



JUNE, 1982

FINAL REPORT

PROCESS WATER USE

Volume 12

Der

LITERATURE AND DATA SEARCH
OF
WATER RESOURCE INFORMATION
OF THE
COLORADO, UTAH, AND WYOMING
OIL SHALE BASINS

LEWIN AND ASSOCIATES, INC.

Denver, Colorado

Washington, D.C.

BUREAU OF LAND MANAGEMENT

Contract YA-553-CT1-1093

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LIST OF VOLUMES

PROCESS WATER USE

Volume 12

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Lewin and Associates, Inc.

Denver, Colorado

Washington, D.C.

For The
Colorado State Office
Bureau Of Land Management
U. S. Department Of Interior
Denver, Colorado

Contract No. YA-553-CT1-1093

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LIST OF VOLUMES

- Volume 1: Users' Guide
- Volume 2: Bibliography of Water Resources Literature
- Volume 3: Bibliography of Water Resources Literature
- Volume 4: Bibliography of Water Resources Literature
- Volume 5: Bibliography of Water Resources Literature
- Volume 6: Topical Bibliography of Water Resources Literature
- Volume 7: Listing of Personnel and Agencies
- Volume 8: Colorado Data Compilations
- Volume 9: Utah Data Compilations
- Volume 10: Wyoming I Data Compilations
- Volume 11: Wyoming II Data Compilations
- Volume 12: Process Water Use

PROCESS WATER USE DATA

Introduction

Water will be used at an oil shale plant during mining and ore processing, in retorting, during shale oil upgrading, and for spent shale disposal and site reclamation. Additional water is required to supply the increased population and other related activities that will accompany development.

The process water use data compilation assembles relevant and recent estimates of on-site process water use for surface and in situ oil shale processes. Water demands associated with off-site infrastructure are not included as they are addressed in the "Present Water Use" data compilations. This compilation focuses on principle sources of information which are process-specific and based on conceptual or detailed engineering designs. Many of the older water estimates which are based on "generic" processes or "secondary" are omitted in this compilation. Of necessity, this compilation is limited to process water use estimates which are in the public-domain. All of the developers certainly have additional water use data which are proprietary. This information, however, should not be significantly different from that presented here.

Process Water Use Estimates

The amount of water required for oil shale development depends largely on the specific retorting process and mining method employed. Some estimates of consumptive use for various in-situ and surface processes, based on our data compilation, are summarized in below:

<u>PROCESS</u>	<u>CONSUMPTIVE USE</u> (gal/bbl)
SURFACE PROCESS	
TOSCO II	116-276
PARAHO DIRECT	64-103
PARAHO INDIRECT	66-164
UNION B	80-155
LURGI	298
MULTIMINERAL (SUPERIOR)	574
IN SITU PROCESSES	
MODIFIED IN SITU	73-278
MODIFIED IN SITU With Aboveground Retorting	67-144
TRUE IN SITU	0.4-102

The ranges for most of these estimates vary over a factor of two. This is due primarily to differences in the process as used in various development scenarios and to different estimation bases (i.e., some include upgrading while others do not). The Union B and Paraho processes require significantly less water than TOSCO II, Lurgi, or the Multimineral Superior process. The range in water consumption for in-situ processes is greater than for surface processes due to uncertainty in retort abandonment water use, and the higher estimates include water for slurry backfilling in situ retorts.

A general comparison of water requirements (not consumptive use) by category for both surface and in-situ processes is presented in below:

UNIT OPERATION	WATER REQUIRED (gal/bbl)	
	<u>SURFACE</u>	<u>IN SITU</u>
Mining and ore processing	15 - 19	6 - 9
Power generation	12 - 22	N/A
Retorting and upgrading	26 - 90	45 - 165
Shale disposal and reclamation	25 - 72	20 - 50
Municipal use	11 - 13	14 - 15

The mining and ore processing category includes water for dust suppression, drilling, ore conveyance, ore crushing, and ore stockpiling. The retorting and upgrading category includes water for cooling tower makeup, boiler makeup, steam and treatment losses, service and fire water, potable and sanitary water, and refining of the shale oil. The shale disposal and reclamation category includes water used for spent shale cooling, transport, compaction, and revegetation. For in situ processes, this latter category includes water used to abandon in situ retorts. The municipal category includes water for mine and plant employees.

This tabulation indicates that most of the water is required for retorting and upgrading, followed by shale disposal and reclamation. No water is needed for power generation in MIS (modified in situ) and MIS/AGR (modified in situ with aboveground retorting of mined shale) processes because power will probably be generated by burning low-Btu gases in open-cycle gas turbines that do not need to be cooled. Cooling water is needed for the surface processes because solid-fuel, steam-cycle systems will likely be used (OTA, 1980). The significant difference in water requirements for mining and ore processing among surface and in situ processes is related to the quantity of raw shale that is mined and handled. In surface processes, about four times as much raw shale is mined and processed as during in situ processes.

The process water use data tabulation contained in Table 1 summarizes the type of information available and specific consumptive use estimates from each principle reference. The Table is organized under the following headings:

A. Source

This column presents the reference and contact from the Bibliography for each "principle" source of process water use data. Addresses and telephone number of the contacts are tabulated in the "Listing of Personnel and Agencies", Volume 7.

PROCESS WATER USE DATA

[illegible]

TABLE 1 (continued)

Source	Surface Processes (gal/bbl)							In-Situ Processes (gal/bbl)				INFORMATION AVAILABLE IN APPENDIX ^h
	Generic Or Other	TOSCO II	Paraho Direct	Paraho Indirect	Union B	Lurgi	Superior	MIS	MIS/AGR ^a	True	Geokinetics	
@ 160.1 Bureau of Land Management, 1982	*f	-	-	-	-	-	-	-	-	-	-	-
@ 160 Bureau of Land Management, 1982	*g	*	*	-	-	-	-	-	-	-	*	-
@ 479 U.S. Dept. of Interior, 1973	Underground Mining <u>108-171</u>	-	-	-	-	-	Surface Mining <u>108-164</u>	-	-	54-102	-	71,T
@ 621 Office of Tech- nology Assessment, U.S. Congress, June 1980	-	180-200 ^d	84-103 ^d	164 ^d	103 ^d	-	-	73-224 ^d	86 ^d	-	-	73,T,D
@ 336 (See 449) U.S. Dept. of Energy, Oct. 1979	-	170-191	64	-	-	-	-	250	165	-	-	81,S,T
@ 484.1 U.S. Dept. of Interior	-	-	-	-	-	-	-	44-90	-	0.4-27	-	91,T
@ 157 Brown, A., Schauer, M.I., Rowe, J.W., and Heley, W., Sept. 1977	-	*e	-	*e	*e	-	-	89	-	68	-	95,T,D
@ 699 (Also See 697,698, 696) Rio Blanco Oil Shale Company (Gulf Oil Corp. and Standard Oil Co. (Indiana)), May 1977	-	-	-	-	-	-	-	-	67	-	-	101,S,T,D
@ 230 C-b Shale Oil Project (Ashland Oil and Occidental Oil Shale), Feb. 1977	-	-	-	-	-	-	-	63	-	-	-	106,T,D
@ 369.1 Fox, J.P., Dec. 1980	-	-	-	-	-	-	-	71-278	144	-	-	110,T

TABLE 1: EXPLANATION OF SYMBOLS AND FOOTNOTES

Symbols

- Indicates no data on process.
- * Indicates estimates not yet available report in progress.

Footnotes To Tables

- a Modified In-Situ (MIS) and Aboveground (AGR) retorting of mined shale.
- b Combined production from 113,000 tons/day based on Superior retorts, 46,400 ton/day based on Union B retorts, and 19,400 ton/day based on TOSCO II.
- c Combined production from 74,900 ton/day based on TOSCO II retorts and 119,000 tons/day based on Paraho direct-mode retorts.
- d Adjusted to exclude municipal demand.
- e Estimated for surface processes are presented, but seem to be inconsistent with other estimates.
- f Chevron STB process. EIS is in draft and final water use figures not available.
- g Includes proposed Syntanna-Utah and Magic Circle processes. Specific process presently unknown. EIS is in draft and final water use figures not available.
- h The first number refers to the the page number in the Process Water Use Data Appendix where more information may be found. The following letters refer to the type of data in the Appendix: S = water balance schematic; T = tabular water balance; D = descriptive text.

B. Consumptive Water Use

This section contains a column for each oil shale process for which relevant water use data has been reported in the open literature. The value of the consumptive water use in gallons per barrel of oil is reported this section. The recorded value is taken directly from the noted source, following appropriate unit conversions. These estimates are process specific and do not include associated domestic use. Any modifications in reported estimates are footnoted. If a reference does not contain data on a process, a dash (-) is recorded. If specific use estimates are not available yet, or if there is some question about the information, an asterisk is recorded (*). It is important to note that the consumptive use estimates reported in different sources are not estimated to the same basis. Before using any of these values, the reader should refer to the data appendix and determine the estimation basis.

C. Information Available in Data Appendix

The Process Water Use Appendix is included to facilitate the use of this compilation and contains tabular and schematic water balances and other descriptive material. This column summarizes the type of information that is available in this Appendix for each reference.

The first number in this column is the page number in the Process Water Use Data Appendix on which information from a reference starts. The letters which follow the page number code the type of information included. The letter "S" indicates that a water balance process flow schematic is included; the letter "T" indicates that a tabular summary of water use by category is included, and the letter "D" indicates that descriptive text is included.

Process Water Use References

The process water use references, summarized in the Process Water Use topical bibliography, contain three types of information: (1) original estimates for specific processes; (2) generic estimates for "typical" surface or in situ processes, derived from the "principal" references; and (3) detailed estimates or estimation procedures for specific categories of water use. Only those "principal" references which contain current, process-specific, original estimates that are based on conceptual or detailed

engineering designs are included in Table 1. Although some of the references that are included summarize or draw upon data in earlier works, (i.e., OTA, 1980; Fox, 1980), they are included because they contain new and original data.

The other important set of references contain detailed information and/or estimation procedures for various water use categories. These references include: Adams and others, 1976 (Ref. 104.1); Cook, 1974 (Ref. 290); Wymore, 1974 (Ref. 878); and Wymore, 1973 (Ref. 879). The first reference in this list contains information on water use during reclamation of an open-pit oil shale mine and the remaining three present water use estimation data and procedures for the reclamation of a surface spent shale disposal area.

The other references not included in Table 1 and not discussed above are either not current and have been superceded by more recent studies, or they are secondary in that they are based exclusively on data in other "principal" references. Some primary reference material has not been included because the published material contained inadequate information to evaluate the estimates. These references are not recommended for use in EIS or other planning studies as sources of process water use data. This does not, however, preclude the use of these references as a source for other types of information.

APPENDIX

PROCESS WATER SELECTED READINGS

<u>Accession Number</u>	<u>Title</u>	<u>Page</u>
181	Bureau of Land Management, 1975	1
784.6	TRW, 1981	7
844	White River Shale Project, 1981	22
569.1	McKee and Kunchal, 1976	26
788	Union Oil Co., 1979	34
702	Rio Blanco Oil Shale Project, 1976	37
422	Gold et al., 1977	43
170	Bureau of Land Management, 1979	56
704	Rio Blanco Oil Shale Project, 1981	62
231	C-b Shale Oil Project, 1976	68
479	U.S. Dept. of Interior, 1973	71
621	Office of Technology Assessment, 1980	73
336	U.S. Dept. of Energy, 1979	81
484.1	U.S. Dept. of Interior, no date	91
157	Brown, et al., 1977	95
699	Rio Blanco Oil Shale Project, 1977	101
230	C-b Shale Oil Project, 1977	106
369.1	Fox, 1981	110

DEPARTMENT OF THE INTERIOR

SUMMARY

FINAL
ENVIRONMENTAL STATEMENT

Department of the Interior, Bureau of Land Management (BLM)

1. Type of action: (X) Administrative () Legislative

2. Brief description of action:

PROPOSED DEVELOPMENT OF OIL SHALE RESOURCES
BY THE
COLONY DEVELOPMENT OPERATION IN COLORADO

Prepared by
Bureau of Land Management
Department of the Interior

3. Summary of environmental effects and adverse environmental effects:

See Attachment.

4. Alternatives considered:

See Attachment.

5. Comments have been requested from the following:

See Attachment.

6. Date draft statement made available to the public or environmental

quality and the public:

Draft Statement: December 12, 1978

Final Statement:

Burt Bertelund.

Director

SUMMARY SHEET

SUMMARY

() Draft

(X) Final Environmental Statement

Department of the Interior, Bureau of Land Management (BLM)

1. Type of action: (X) Administrative () Legislative

2. Brief description of action:

The proposed Federal action is the consideration of a right-of-way permit for an oil shale products pipeline from a plant site in Colorado to Lisbon Valley, Utah. Directly related to this Federal action is the development of a 4,000-acre underground oil shale mine; mining of 61,000 tons per day of oil shale for 20 years; construction and operation of a 47,000-barrel-a-day shale oil plant; construction of two dams - Davis Gulch processed oil shale disposal catchment and Middle Fork flood control; disposal of processed oil shale on 800 acres; construction of a 194-mile, 16-inch shale oil pipeline from the plant site on the Roan Plateau to Lisbon Valley, Utah; development of a 15-mile-long service corridor in the Parachute Creek valley; construction of a 75-acre terminal site in Grand Valley; construction of two 230 kv powerlines to the plant site; a 337-acre exchange of land between BLM and Colony Development Operation; and diversion of up to 7,200 acre-feet per year from the Colorado River.

3. Summary of environmental impacts and adverse environmental effects:

See Attachment.

4. Alternatives considered:

See Attachment.

5. Comments have been requested from the following:

See Attachment.

6. Date draft statement made available to the Council on Environmental

Quality and the public:

Draft Statement: December 12, 1975

Final Statement:

PROPOSED ACTION

maintenance, operations, laboratory, safety and security facilities. Effluent from the sewer will be treated in a secondary package aeration plant. The aeration plant will produce a clarified water and sludge.

Sludge from the aeration plant will flow to a sludge surge tank and then to the processed shale moisturizer in the pyrolysis unit. The sludge will ultimately be mixed with the processed shale.

Colony is also considering an alternate method of sludge disposal. The alternate method would require drying the sludge and disposal as a solid in the processed shale embankment.

Clarified water from the aeration plant will be treated in a hypo-chlorination unit and then discharged into the clean water guard pond. Effluents from the clean water guard pond will be used as water for the processed shale moisture.

An estimated 20,000 gallons per day of sludge and clarified water will be produced at the plant site.

Water treatment systems outside of the utility unit which have been previously discussed in the section on retorting and upgrading include the following:

- Pyrolysis unit, water scrubber system

- Foul water stripper

- Coke unit, coke fines/water separator

- Ammonia separation unit, sour water stripper

UTILIZATION

Water will be utilized for the purposes indicated in the following plant activities:

- Mining - 350 gpm - Wetting down blasted shale, mine roads, and drilling dust suppression.

SOLID WASTE DISPOSAL

- Crushing, conveying, and coarse ore storage - 150 gpm - Suppression of dust with water sprays.
- Retorting and upgrading - 3,655 gpm - Cooling water, steam generation, processed shale moisturizing, and coke removal.
- Processed shale disposal - 1,570 gpm - Dust control, revegetation program, and leaching of salts.
- General plant and personnel use - 265 gpm - Utility water, fire protection, potable water, and sanitary sewage.
- During construction - Water is required for concrete manufacture, dust control, compaction of grades and fills, and other general and construction personnel uses - 800 to 1,200 acre-feet per year.

The usage and disposition of water during normal operations is shown in Figure II-32.

Water supplied to the plant will eventually be consumed or released to the atmosphere by evaporation. Water used in the processed shale moisturizing process will constitute a major consumption of water. The processed shale pile will be the point of disposal for waste water streams which are not recycled. Other consumptive uses of water will be: the steam-reforming process to make hydrogen; drinking water; and the revegetation program. Water used for dust control in mining and crushing operations eventually will be released to the atmosphere by evaporation. Water used for moisturizing processed shale or for dust control on the processed shale embankment will either evaporate or become part of the processed shale embankment.

Water recovered from the various process units and water treatment facilities within the plant complex will either be recycled within the retorting and upgrading units or utilized to moisten processed shale.

The cooling water system is comprised of a complex network of piping over the entire processing area. About 36,000 gpm of cooling water will circulate

SOLID WASTE DISPOSAL

throughout the plant and will eventually return to a multiple cell cooling tower. The cooling tower will incorporate an induced draft system and will produce a visible water vapor plume after the vapors have cooled to their condensation point. Water evaporated in the cooling towers will not contain dissolved salts. Cooling water blowdown will be used to moisturize processed shale.

All water used at the plant site will be consumed or evaporated. No discharges will be made into Parachute Creek.

DAMS

Two dams will be constructed to provide a combination of flood and water quality protection and to provide for limited water storage. Both dams will be designed utilizing standards delineated by the Bureau of Reclamation text entitled Design of Small Dams and in strict accordance with safety standards of the Colorado Division of Water Resources. The final design of the dams, according to Colony, will include a cutoff trench, grout curtain, or impermeable blanket as required to assure the water holding capabilities of the dams. Figure II-33 shows a typical cross section of the type of design that will be utilized for both Davis Gulch and Middle Fork dams.

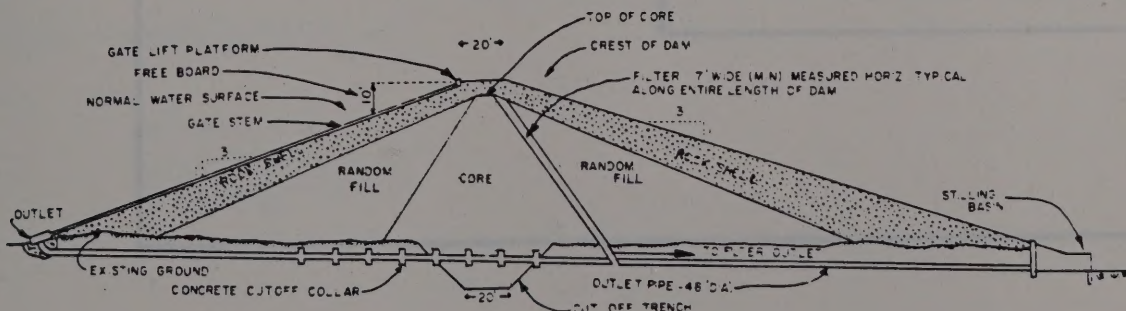


FIGURE II-33
CROSS SECTION OF A TYPICAL EARTH & ROCK FILL DAM (1)

-6-

-6 A-

INTERIM REPORT

Conceptual Process Designs: Union B, Paraho, and Tosco II

Naval Oil Shale Reserves
Management Support and
Systems Engineering Project

Performed under Contract No. DE-AC01-78RA32012
for the U.S. Department of Energy

February 1981

TRW ENERGY ENGINEERING DIVISION
8301 GREENSBORO DRIVE, McLEAN, VIRGINIA 22102 • (703) 734-6500

Table 2-3. Estimated Water Requirements

	<u>PARAHO DH PLANT</u>	<u>TOSCO II</u>	<u>PARAHO IH PLANT</u>	<u>UNION B</u>
PRODUCTION RATE BBL/DAY	51,134	49,707	50,033	53,294
WATER, GPM BBL/DAY	2,300 78,857	4,140 141,943	2,300 78,857	5,750 197,143
BBL WATER/BBL OIL	1.54	2.86	1.58	3.70

3.8 WATER BALANCE

Figure 3-6 shows the water balance for the entire plant. Most of the water is used in process loops with continuous recycle. The shale oil retorting process generates approximately 363 GPM of foul water. This water is used for moisturizing spent shale, but is not enough for the entire moisturizing operation. Water is used for process cooling and steam generation on a steady-state recycle basis. Unsteady-state requirements include plant and mine washdown water, fire protection storage, and potable water for safety shower and eyewash stations. No recycle of plant washdown water or storm water drainage is assumed. Forthcoming hydrological information will be used to estimate recycle potential. The water delivery system will be designed to supply three times the steady-state operating usage with substantial supply in plant site storage. Water requirements are shown in Table 3-2.

An attempt will be made to conserve the maximum amount of water. The process requires about 75,000 GPM of recycling cooling water from 110° to 80°F. Usage of a conventional induced draft water cooling tower would entail the loss of approximately 3,200 GPM through blow-down and evaporation. This water must then be pumped from the Colorado River to compensate for this loss -- approximately an added 5,000 HP per year. Due to the scarcity of the water resource and the likelihood of Colorado legislation restricting cooling towers, air-cooled "fin-fan" units were selected for the process water cooling. Air units have no water losses. The capital cost of these units (\$15 to \$20 million) is four to five times the comparable water cooling tower, but their employment reduces the potential of plant shutdown due to a lack of water. Operating costs would be somewhat less, however, given the large HP requirement for pumping and the ability to adjust the fan "bite" during colder weather. The added capital cost of air-cooled units is small in relation to the total plant capital cost and the enormous amounts of water that can be conserved. These units are being commonly used, particularly in the Middle East.

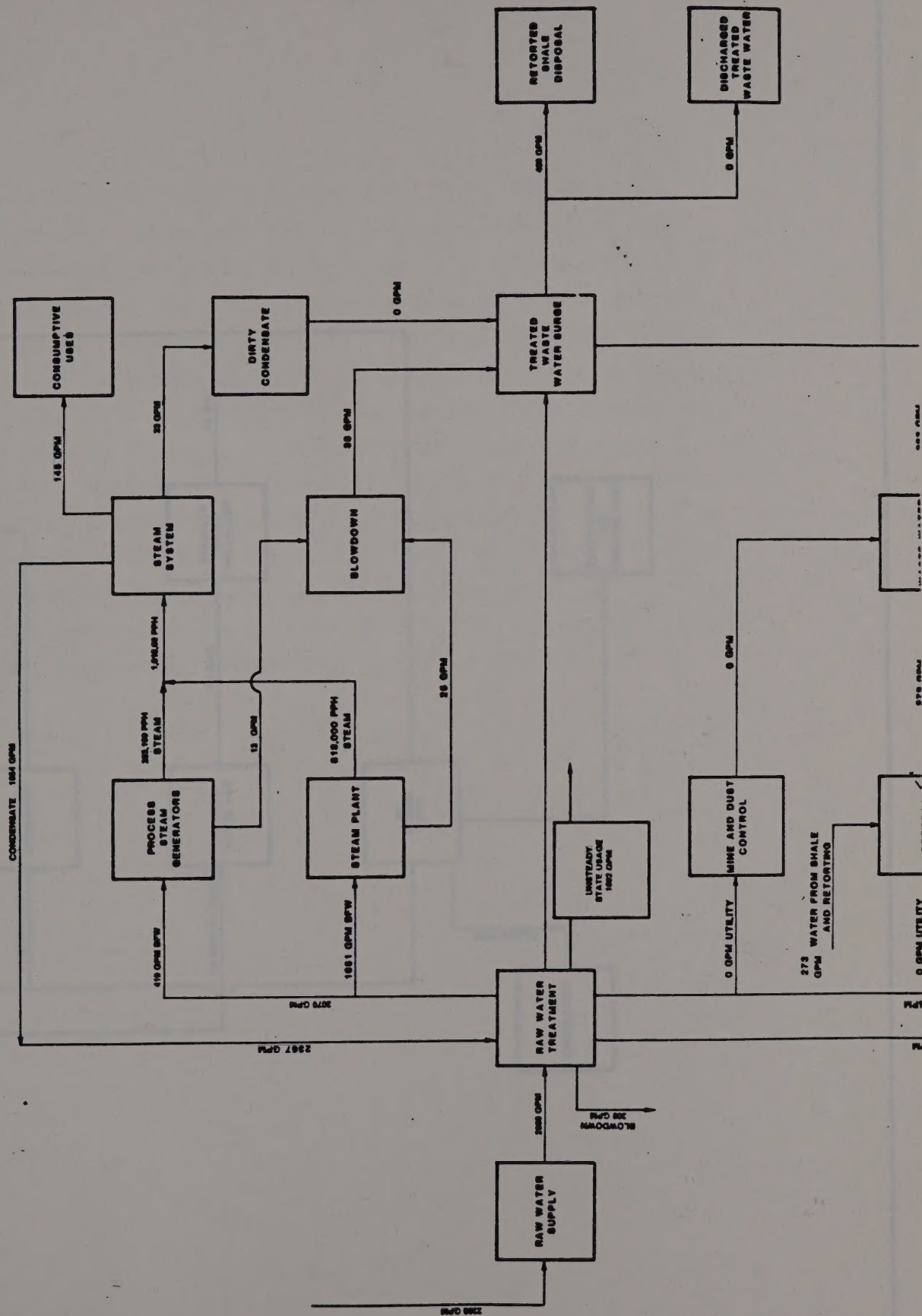


Figure 3-6. Water Balance for Paraho DH Process

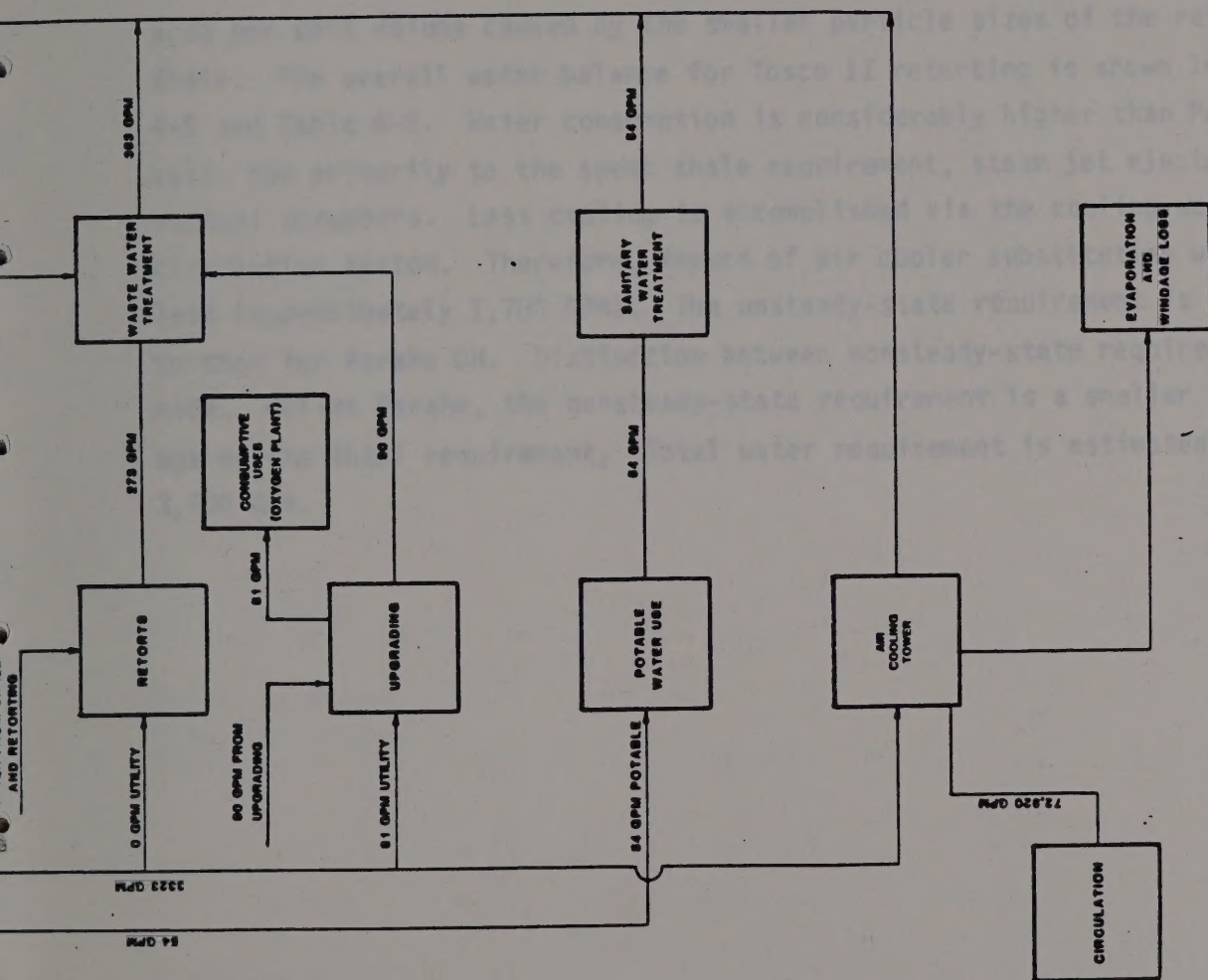


Figure 3-6. Water Balance for Paraho DH Process

TOSCO II PROCESS

4.8 WATER BALANCE

The discussion of Section 3.8 is applicable here. One major difference is amount of water required for disposal of the spent shale. Whereas the requirement was 5 wt% for the Paraho, it increases to 12 wt% for the Tosco II system. This is due to proportionately larger surface area per unit volume caused by the smaller particle sizes of the retorted shale. The overall water balance for Tosco II retorting is shown in Figure 4-5 and Table 4-2. Water consumption is considerably higher than Paraho DH case, due primarily to the spent shale requirement, steam jet ejectors, and venturi scrubbers. Less cooling is accomplished via the cooling water circulation system. Therefore, impact of air cooler substitution will be less (approximately 1,700 GPM). The unsteady-state requirement is similar to that for Paraho DH. Distinction between nonsteady-state requirements is made. Unlike Paraho, the nonsteady-state requirement is a smaller percentage of the total requirement. Total water requirement is estimated at 3,600 GPM.

Table 4-2. Estimated Water Requirements - Tosco II (GPM)

	<u>Feed</u>	<u>Recycle</u>	<u>Consumed</u>	<u>Treated</u>
Steam Usage	1,325	467	858 ¹	20
Process Retorts Water Generated	-413		-413	413
Process Retorts Water Required For Process	1,130		740	390
Upgrading - Including Hydrogen Consumption	3,096		220	89
Potable Water	24		24	24
Shale Disposal Water	724		724	
Process Cooling		40,000		
Net Water Required For Shale Disposal (Treated and Direct		1,660	2,153	936
Net Plant Water Consumed Steady- State		2,153		

¹ 479 GPM To Retort and Upgrade Requirements

Table 4-2. Estimated Water Requirements - Tosco II (GPM) (Continued)

	<u>Feed</u>	<u>Recycle</u>	<u>Consumed</u>	<u>Treated</u>
Net Estimated Unsteady-State Requirement ¹		850		
System Delivery		3,600		
15% Blowdown		540		
Total Water Required 4,140				

¹ Basis

	GPM
Steady-State System Loss (0.5% of circulation rate)	200
Maintenance, cleaning, construction	50
Mining water washdown	300
Fire pond evaporation	50
Plant washdown, housekeeping	100
Safety showers, misc.	50
	750
Steady-State	2,153
Total Water Required (Baseline)	2,900
Miscellaneous (evaporation from reservoir, oil rinse, off spec material work away, etc.)	700
Continuous 24-Hr Maximum	
	3,600

NOTE: 478 GPM TO RETORT AND UPGRADING

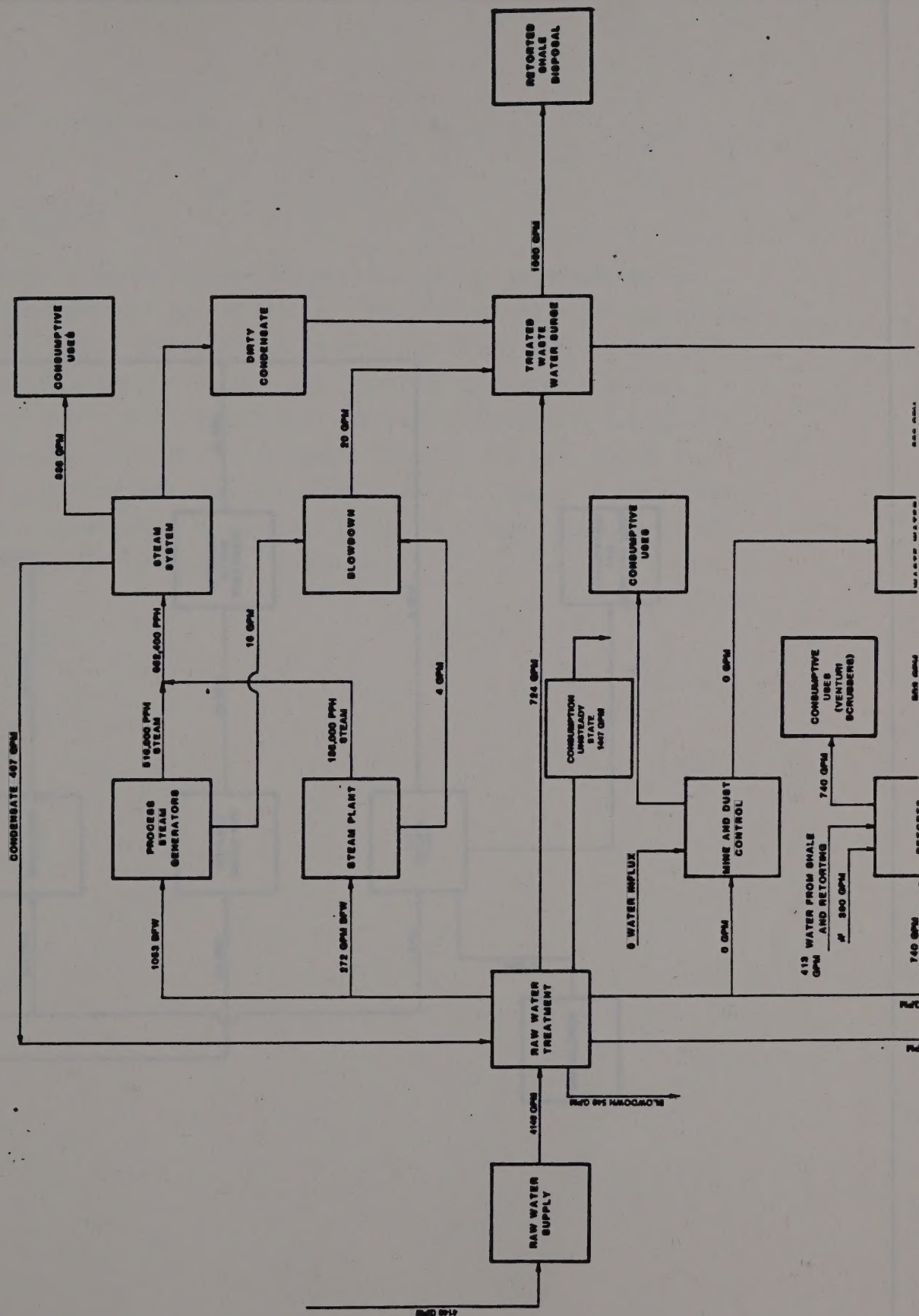


Figure 4-5. Water Balance for Tosco II Process

PARAND INDIRECT-HEATED PROCESS

5.5 WATER BALANCE

The discussion under Section 3.8 applies. Water requirements for spent shale disposal will be comparable. The overall water balance for the Parand indirect-heated retort system is shown in Figure 5-5 and Table 5-1. Distinction is made between steady- and nonsteady-state requirements. Steady-state is only a small fraction of the Parand III system, due to lack of steam generation from condensation gases. Roughly the same amount of cooling takes place in the same circulating loops. Impact of air cooler

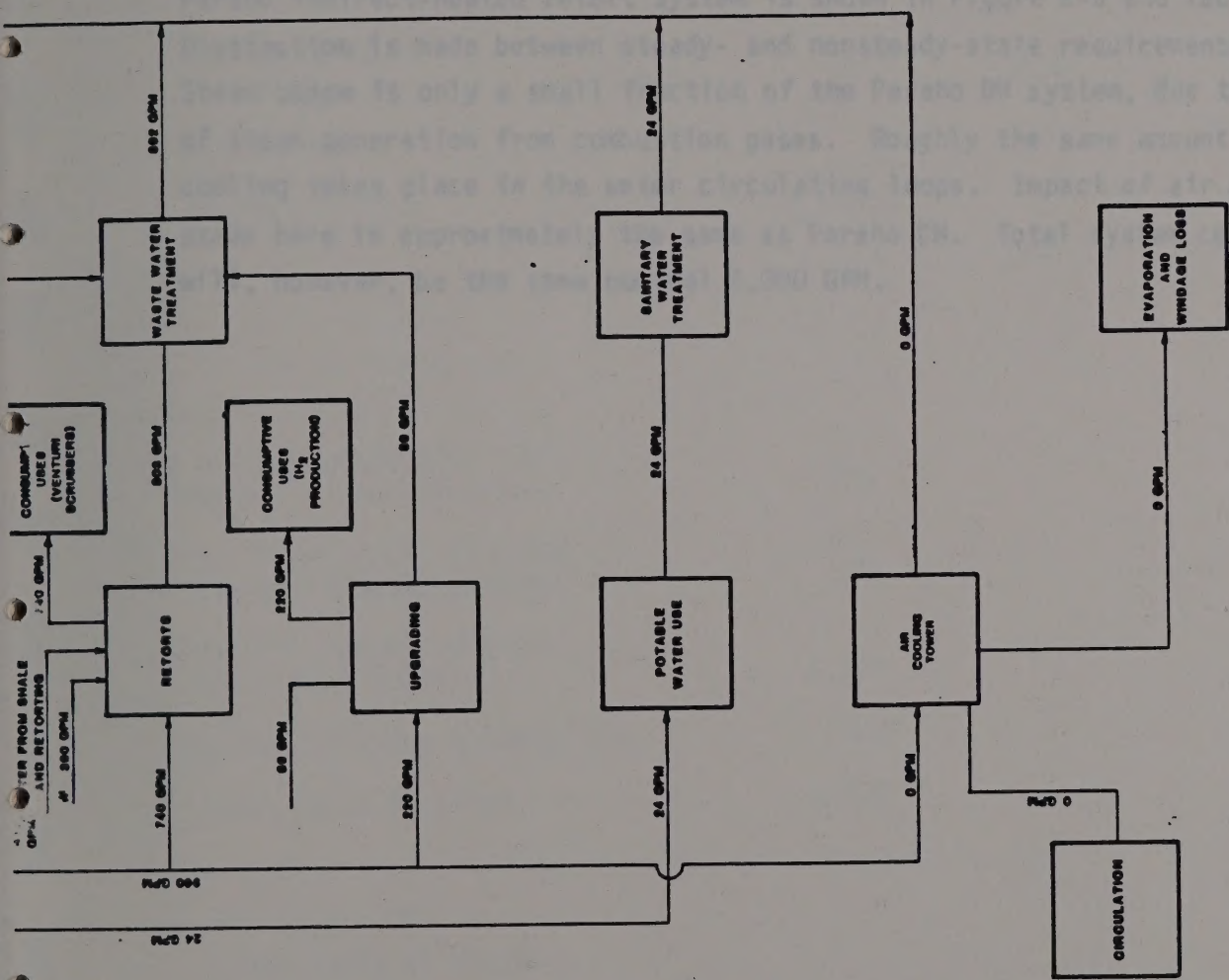


Figure 4-5. Water Balance for Tosco II Process

Table 5-1. Estimated Water Requirements - Paraho DH System (GPM)

PARAHO INDIRECT-HEATED PROCESS

	Recycle	Consumed	Treated
Steam Usage	220	207	100

5.8 WATER BALANCE

The discussion under Section 3.8 applies. Water requirements for spent shale disposal will be comparable. The overall water balance for the Paraho indirect-heated retort system is shown in Figure 5-5 and Table 5-1. Distinction is made between steady- and nonsteady-state requirements. Steam usage is only a small fraction of the Paraho DH system, due to lack of steam generation from combustion gases. Roughly the same amount of cooling takes place in the water circulating loops. Impact of air cooler usage here is approximately the same as Paraho DH. Total system capacity will, however, be the same nominal 2,300 GPM.

*23 GPM to upgrading

Net Treated Water For Usage In Shale Disposal	721
Net Plant Water Consumed Steady-State Requirement	477
Net Estimated Unsteady- State Requirements	1,328
System Delivery Standby	300
Total Water Required	2,300

1 Same basis as Paraho
DH applies

Table 5-1. Estimated Water Requirements - Paraho IH System (GPM)

	<u>Feed</u>	<u>Recycle</u>	<u>Consumed</u>	<u>Treated</u>
Steam Usage	555	367	188*	8
Process Retort Water Generated	-471		-471	471
Upgrading Water Generated	-111		-111	184
Upgrading Water Needed	224		224	
Potable Water	60		60	60
Process Cooling		80,000	—	—
			472	721
*73 GPM to Upgrading				
Net Treatment Water For Usage In Shale Disposal		721		
Net Plant Water Consumed Steady-State Requirement		472		
Net Estimated Unsteady- State Requirements ¹		1,528		
System Delivery Blowdown 15%		300		
Total Water Required		2,300		

¹ Same basis as Paraho
DH applies

WATER BALANCE

WATER BALANCE

The discussion in Section 5.4 is general. Overall water usage is shown in Table 5-1 and Figure 5-4. Water usage is greatly increased due to the requirements of the wet electroplating operations. Pipes are similar to those of Table 11 and require considerable maintaining water for

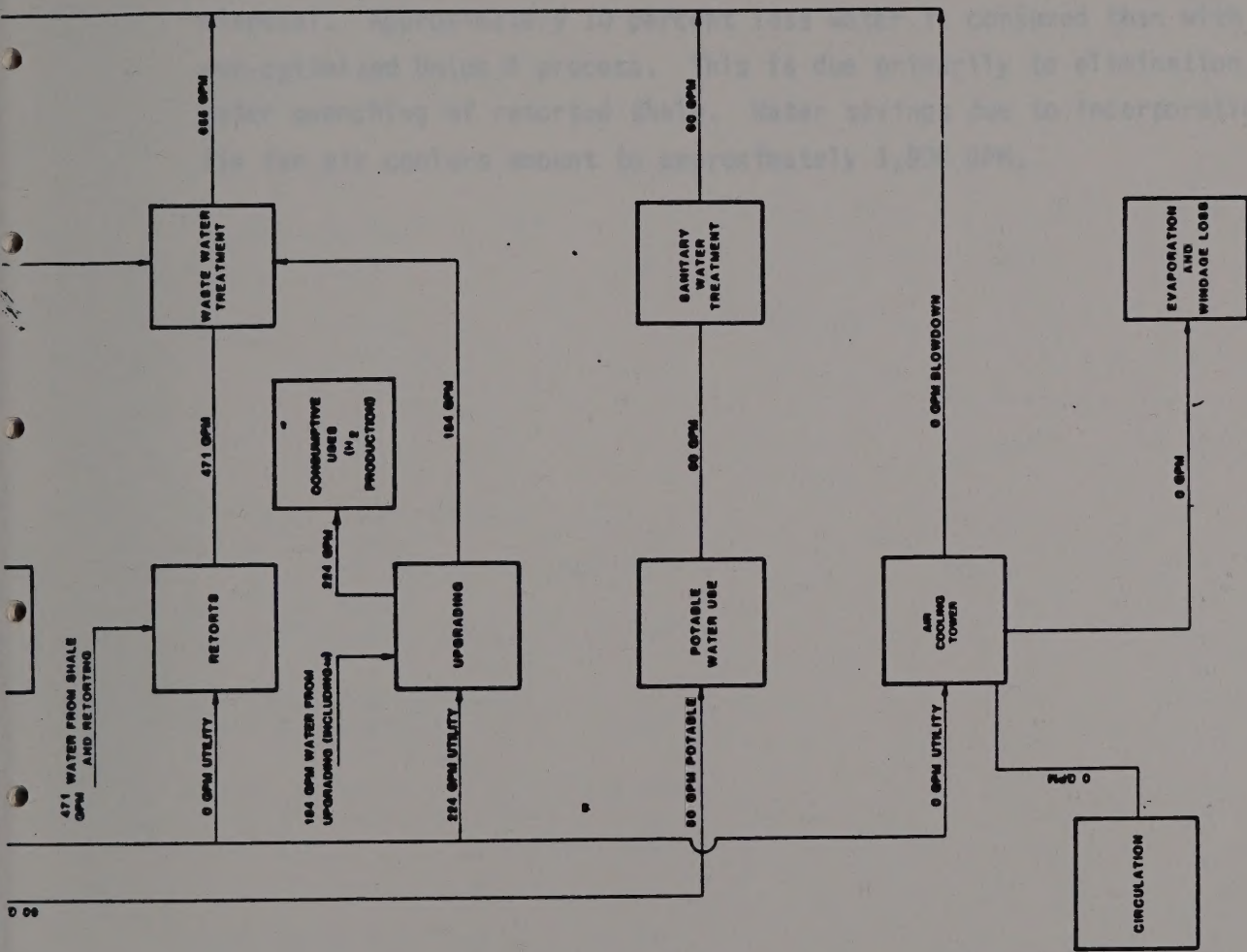


Figure 5-5. Water Balance for Paraho-IH Process



Table 6-1. Estimated Water Requirements - Optimized Union B (GPM)

	<u>Feed</u>	<u>Recycle</u>	<u>Consumed</u>	<u>Treated</u>
Steam Usage	2,099	1,212	887	775
Electrostatic Precipitator	2,500		2,500	
Process Retorts Water Production	-200		33	233
Upgrading - Including Hydrogen Production	195			195
Potable Water	60		60	60
Process Cooling Shale Disposal	223		223	
Process Cooling		50,000		
			3,643	1,263
Net water Required For Shale Disposal	1,484			
Net Plant Water Consumed Steady-State	3,643			
Net Estimated Unsteady- State Requirement ¹	1,357			
System Delivery	5,000			
15% Blowdown	750			
Total Water Required	5,750			

¹Basis

.5% Steady-state system loss	250
Maintenance, cleaning, construction	50
Mining water washdown	300
Fire pond evaporation	50
Plant washdown, housekeeping	100
Safety showers, miscellaneous	50
	800

Table 6-1.. Estimated Water Requirements - Optimized Union B (GPM)
(Continued)

¹Basis (Continued)

Miscellaneous (Evaporation from
reservoir, oil rinse, workaway
of off-spec material, etc.)

550

Total Unsteady-State
Continuous 24-Hour Maximum

1,350 GPM

6.9 FUEL BALANCE

As evident below, the plant is fuel-sufficient requiring no usage of
product oil.

	<u>10⁶ Btu/hr</u>
Fuel required	1,155
Feed to hydrogen plant	854
Total Fuel	2,009
H ₂ S Free Gas	2,009
Fuel Oil Consumed	-0-

Electric Power Requirements¹

Retorting	106.0
Upgrading	15.0
Gas Treatment	4.0
Hydrogen Production	4.0
Water Treatment	.3
Air Cooling Fans	<u>5.0</u>
TOTAL	134.3

¹Not included is the off-site requirement at the Colorado River Pumping
Station estimated at 5.0 MWe.

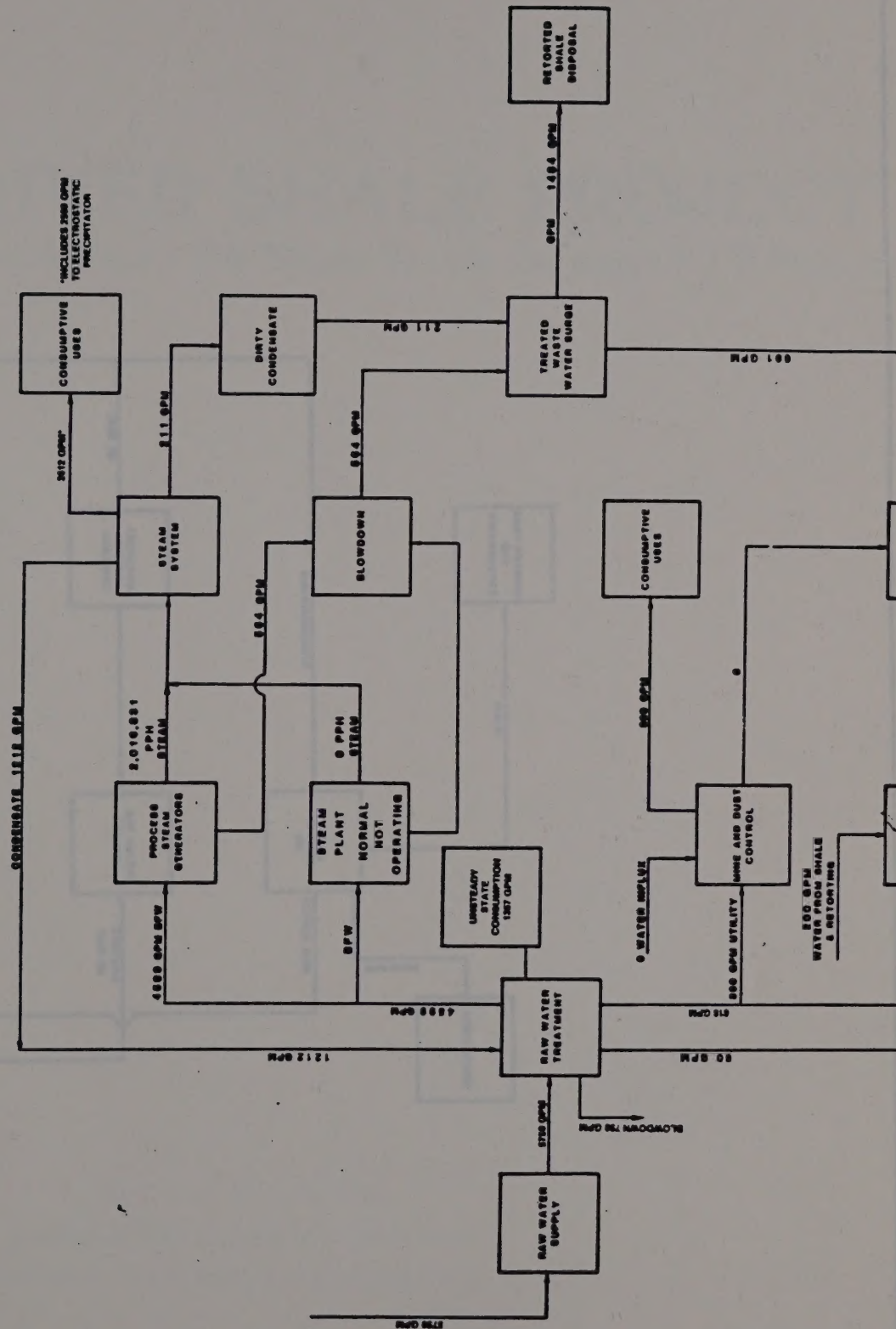
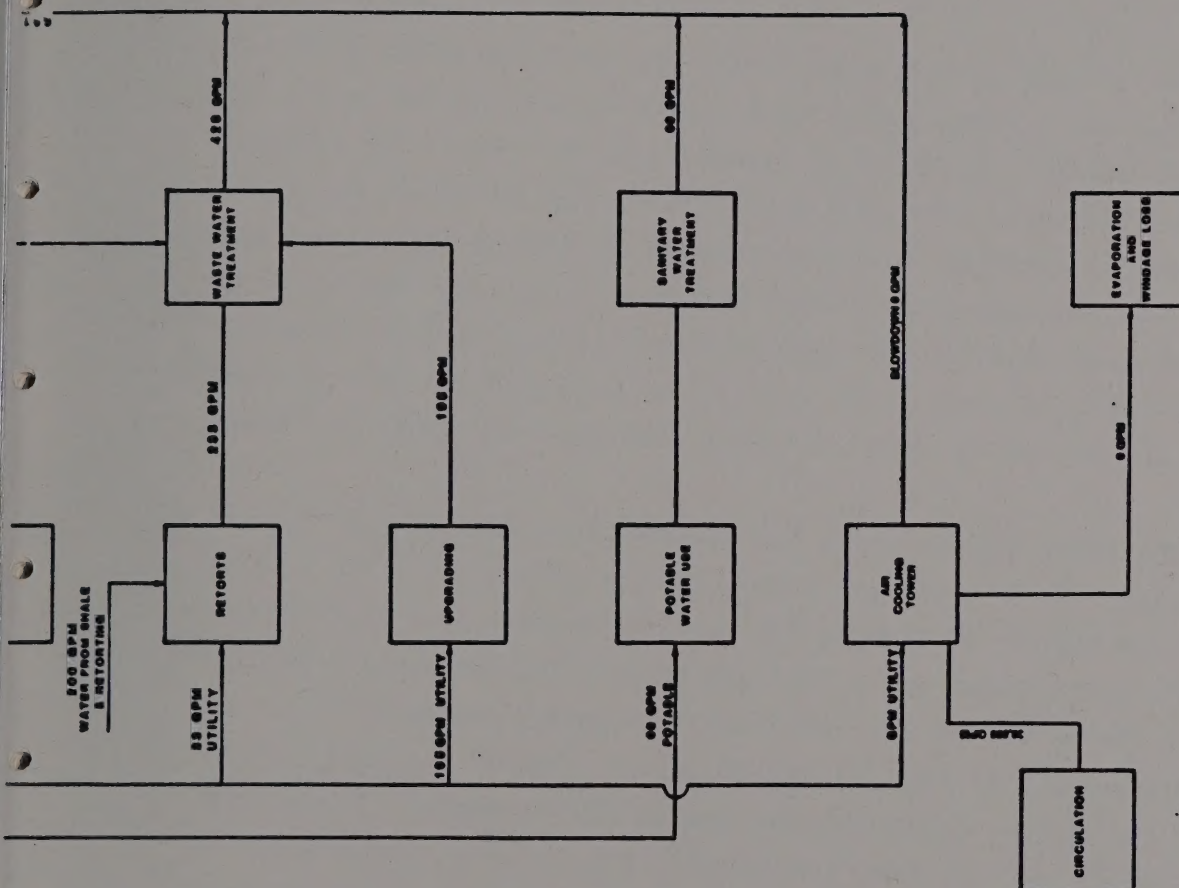


Figure 6-4. Union B Optimized Water Balance

WHITE RIVER SHALE PROJECT

Detailed Development Plan • Oil Shale Tracts Ua and Ub • Volume 1





WHITE RIVER SHALE PROJECT

Detailed Development Plan • Oil Shale Tracts Ua and Ub • Volume I

1.1 CURRENT PROJECT DESCRIPTION

The White River Shale Project (WRSP) is a joint project of Phillips Petroleum Company, American Shale Development Company, and White Shale Oil Company. The intent of these owners is to develop Tracts Ua and Ub in northwestern Utah to produce commercial quantities of shale oil. The project is planned for prompt development with 12 years (1981 to 1993), or until a commercial production will be achieved. Commercial production will continue until the contract resources are exhausted. This is expected to occur in 1993. However, additional reserves will be developed and the life of the project substantially extended.

Phase I will consist of an underground mine, surface retorting, and Phase II will consist of an open-pit mine, surface retorting, and transportation of approximately 10,000 barrels per acre per day (BPD) of synthetic shale oil off site by pipeline. The capacities of the reserves are 11,000 BPD per acre per day (BPD) for the Ua tract and 10,000 BPD for the Ub tract. Phases I and II will follow the same general plan, and the ultimate full development plant will include up to 10,000 BPD Superior retort, four 11,000 BPD Phase II retorts, four 10,000 BPD Phase II retorts, and two 8,000 BPD Phase II retorts. Total initial production will be approximately 10,000 BPD in Phase I and 10,000 BPD in Phase II.

Section 1: Introduction

Section 2: Description of Project Area

Section 3: Description of Proposed Action

Prepared by Bechtel Petroleum, Inc. • San Francisco • Job 14188 • August 1981

WHITE RIVER SHALE PROJECT

Detailed Development Plan - On State Tracts 1A and 1B - 1981

Project: White River Shale
Location: On State Tracts 1A and 1B
Date: 1981

Project: White River Shale
Location: On State Tracts 1A and 1B
Date: 1981

Section 1

INTRODUCTION

1.1 SUMMARY PROJECT DESCRIPTION

The White River Shale Project (WRSP) is a joint project of Phillips Petroleum Company, Sunoco Energy Development Company, and Sohio Shale Oil Company. The intent of these owners is to develop Federal Oil Shale Lease Tracts Ua and Ub in northeastern Utah to produce commercial quantities of shale oil. The project is planned for phased development over 12 years (1981 to 1993), at which time full commercial production will be achieved. Commercial operation will continue until the on-tract resources are exhausted. This is expected to occur in 2007. However, availability of other nearby oil shale resources may extend the life of the project substantially.

Phase I will consist of an underground mine, surface retorting in one Union B and one Superior retort, onsite upgrading of the shale oil, and transportation of approximately 14,840 barrels per stream day (BPSD) of synthetic crude oil off site by pipeline. The capacities of the retorts are 11,600 tons per stream day (TPSD) for the Union B retort and 13,000 TPSD for the Superior retort. Phases II and III will follow the same general plan, and the ultimate full commercial plant will include one 13,000 TPSD Superior retort, four 11,600 TPSD Union B retorts, four 25,000 TPSD Superior retorts, and two 9,700 TPSD TOSCO II fines retorts. Total shipped production will be approximately 56,875 BPSD in Phase II, and 106,300 BPSD in Phase III.

THE HISTORY OF THE UNITED STATES

The history of the United States is a story of the growth of a nation from a collection of small, separate colonies to a great, unified country. It is a story of the struggles of the people to establish a government that would protect their rights and promote their welfare. It is a story of the triumphs of the American spirit and the sacrifices of the American people.

From the first settlement of the Pilgrims in 1620 to the present day, the United States has been a land of opportunity and freedom. It has been a land where the people have been able to create a government that is truly of the people, by the people, and for the people. It has been a land where the people have been able to achieve the greatest of all things: a life of peace, prosperity, and happiness.

3.14.3 PHASE II AND III SYSTEM

3.14.3.1 Water Requirements

The ultimate Phase III water requirements are estimated to be 14,012 gpm or about 22,600 acre-feet per year, as shown in Table 3.14-2. A further discussion is found in Section 7.14.

Table 3.14-2

PHASE III WATER REQUIREMENTS^(a)

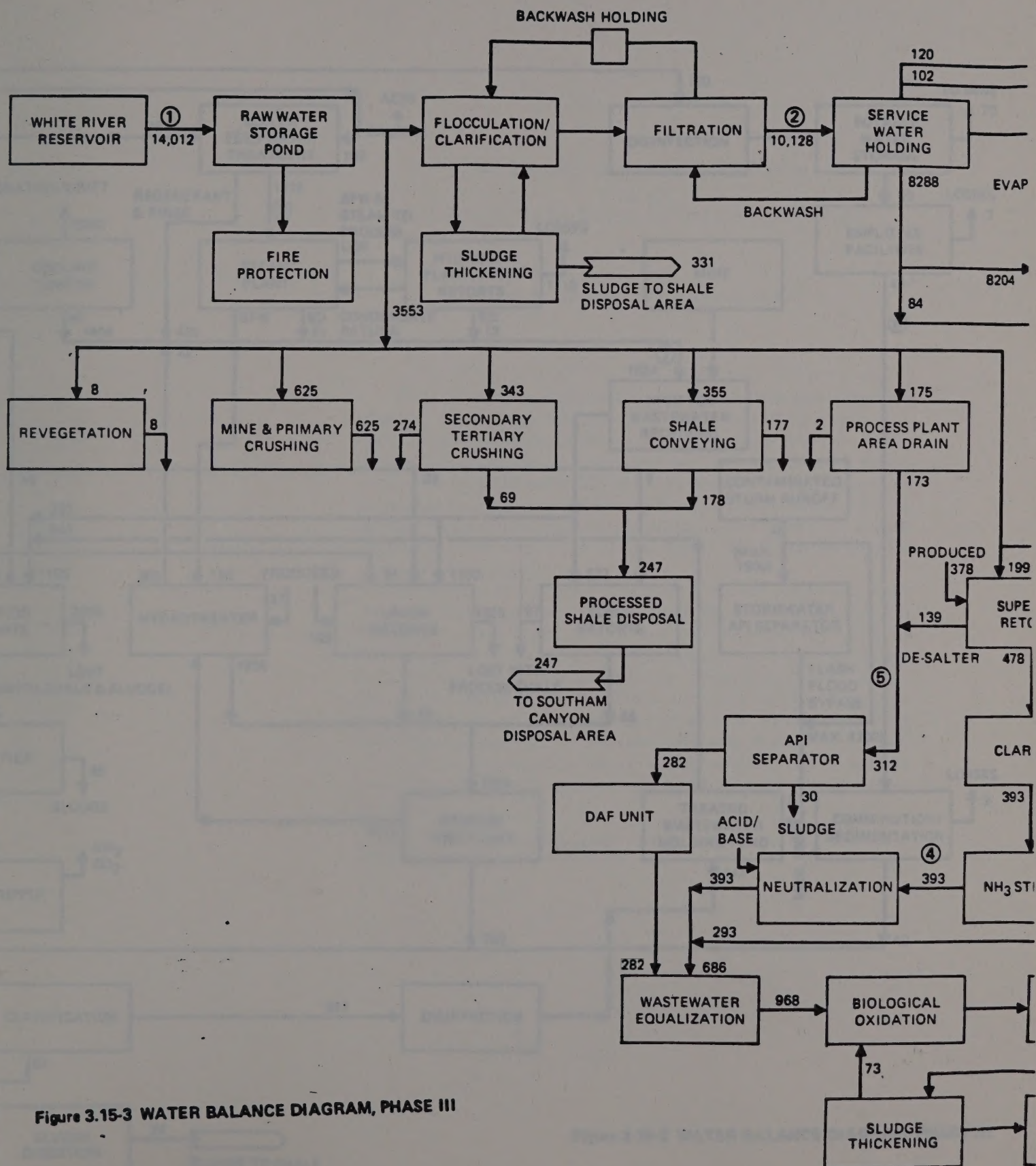
Use	Annual Average	
	Gallons per Minute	Acre-Feet per Year
Cooling Tower Evaporation	6,800	10,970
Shale Quenching and Dust Control	5,007	8,080
Process Plant and Miscellaneous Losses Including Evaporation	2,205	3,550
Total Consumption	14,012	22,600

(a) Dry year basis. No allowance for annual rainfall.

3.14.3.2 Facilities

The water supply facilities for Phases II and III consist of:

- A pumping station located on the south bank of the reservoir on the White River (scheduled for construction by the state of Utah during Phase I)
- A 24-inch-diameter pipe to an on-tract storage pond
- An expanded water distribution system in the plant area



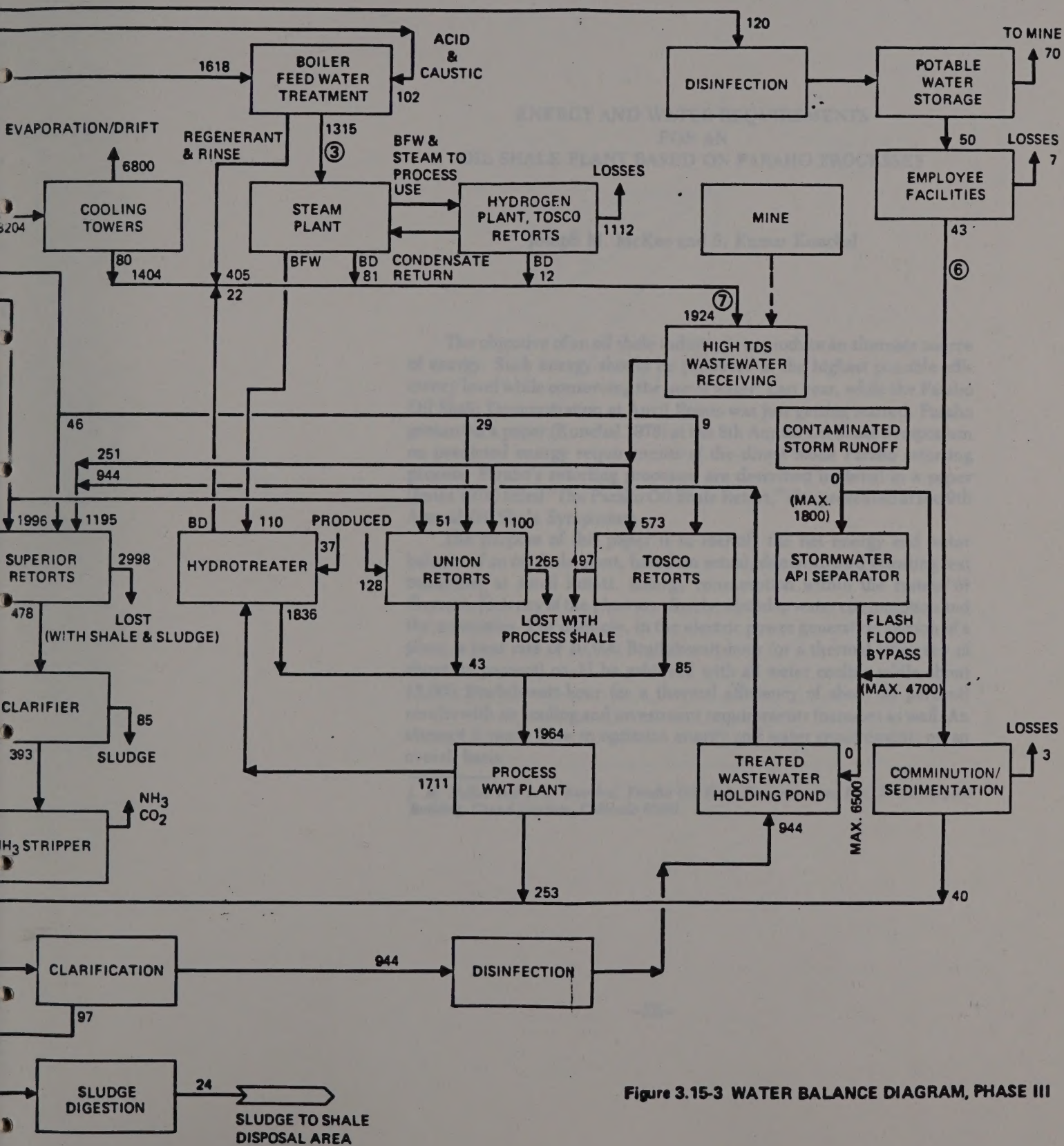


Figure 3.15-3 WATER BALANCE DIAGRAM, PHASE III

ENERGY AND WATER REQUIREMENTS FOR AN OIL SHALE PLANT BASED ON PARAHO PROCESSES

Joseph M. McKee and S. Kumar Kunchal

The objective of an oil shale industry is to produce an alternate source of energy. Such energy should be produced at the highest possible efficiency level while conserving the use of water. Last year, while the Paraho Oil Shale Demonstration at Anvil Points was just getting started, Paraho presented a paper (Kunchal 1975) at the 8th Annual Oil Shale Symposium on predicted energy requirements of the direct mode Paraho retorting process. Paraho's retorting processes are described in detail in a paper (Jones 1976) titled "The Paraho Oil Shale Retort," also presented at the 9th Annual Oil Shale Symposium.

The purpose of this paper is to identify the net energy and water balance of an oil shale plant, based on actual, demonstrated retorting test conditions at Anvil Points. Energy consumption within the system or thermal efficiency of the plant are closely related to water consumption and the economics. For example, in the electric power generation section of a plant, a heat rate of 10,000 Btu/kilowatt-hour (or a thermal efficiency of about 34 percent) could be achieved with all water cooling while about 15,000 Btu/kilowatt-hour (or a thermal efficiency of about 23 percent) results with air cooling and investment requirements increases as well. An attempt is made here to optimize energy and water requirements on an overall basis.

J. M. McKee and S. K. Kunchal, Paraho Oil Shale Demonstration, Inc., 300 Enterprise Building, Grand Junction, Colorado 81501.

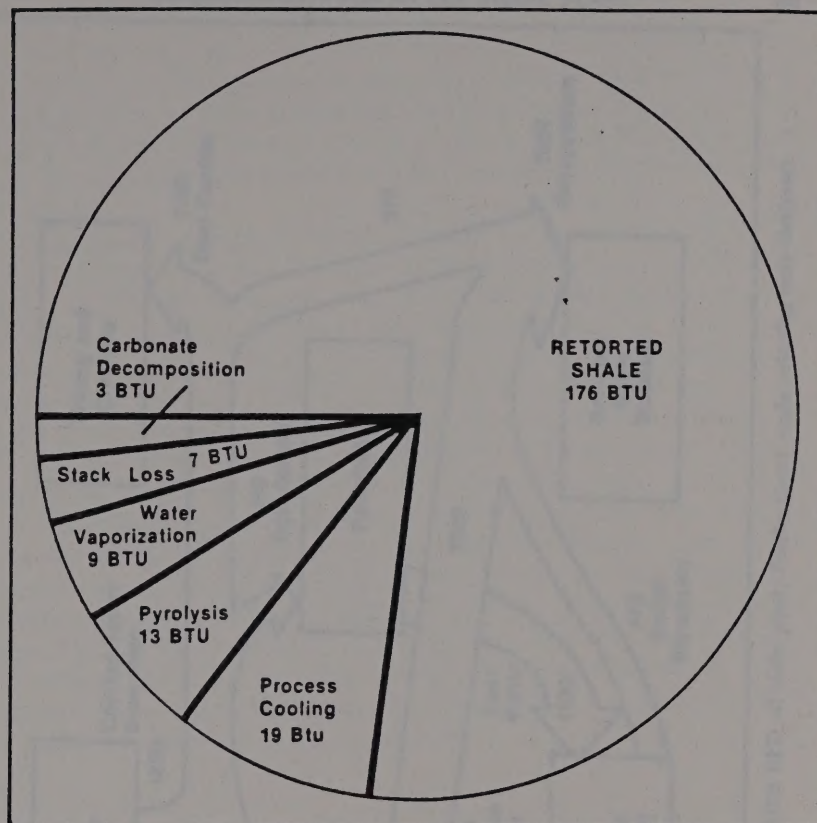
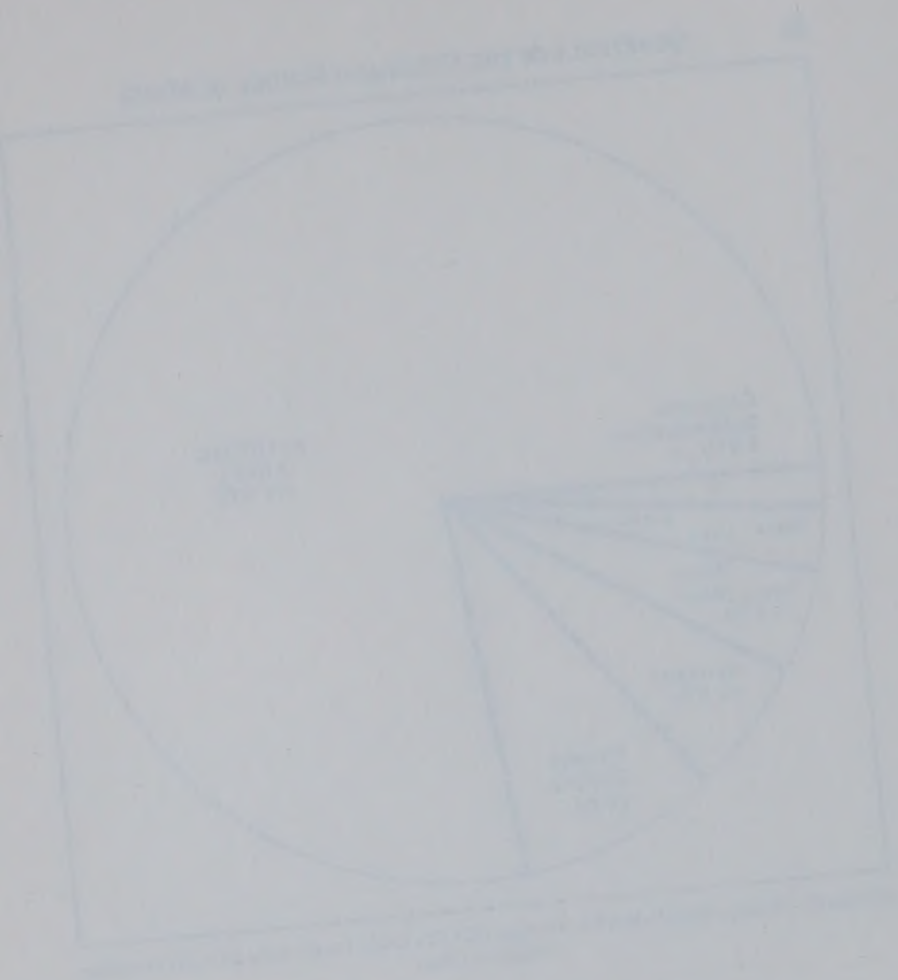


FIGURE 6.—Energy distribution for retorting (227 Btu total), Paraho indirect mode retorting (billions of Btu).

WATER REQUIREMENTS—PARAHO DIRECT MODE

Figure 7 shows an overall water balance for an oil shale plant using the direct mode. A total of 10,000 acre-ft/yr (6,200 gpm or about 2.1 barrels of water per barrel of crude shale oil) are consumed. The majority of this water, 8,160 acre-ft/yr., goes to the cooling tower which supplies all cooling demands for the entire plant, including the electric power plant. The cooling tower load is based on no exportation of electric power. Cooling tower blowdown (1,630 acre-ft/yr) is routed to a pool for use in dust control and vegetation of processed shale. Water treating sludge comprises 160 acre-ft/yr also used for dust control and vegetation. Mining and crushing requires 1,260 acre-ft/yr for dust control.



Analysis of Expenditure Patterns

The data presented in the pie chart illustrates the distribution of total expenditure across various categories. The most significant finding is that 'Other' accounts for 50% of the total, indicating a large portion of the budget is allocated to unspecified or miscellaneous items. This suggests a need for further breakdown of this category to understand its components. Transportation and Medical expenses each represent 15% and 10% of the total, respectively, showing they are the next largest categories. Housing, Food, and Utilities follow, each accounting for 10%, 8%, and 7% of the total expenditure. The chart effectively visualizes the relative importance of each category in the overall budget, with 'Other' being the dominant factor.

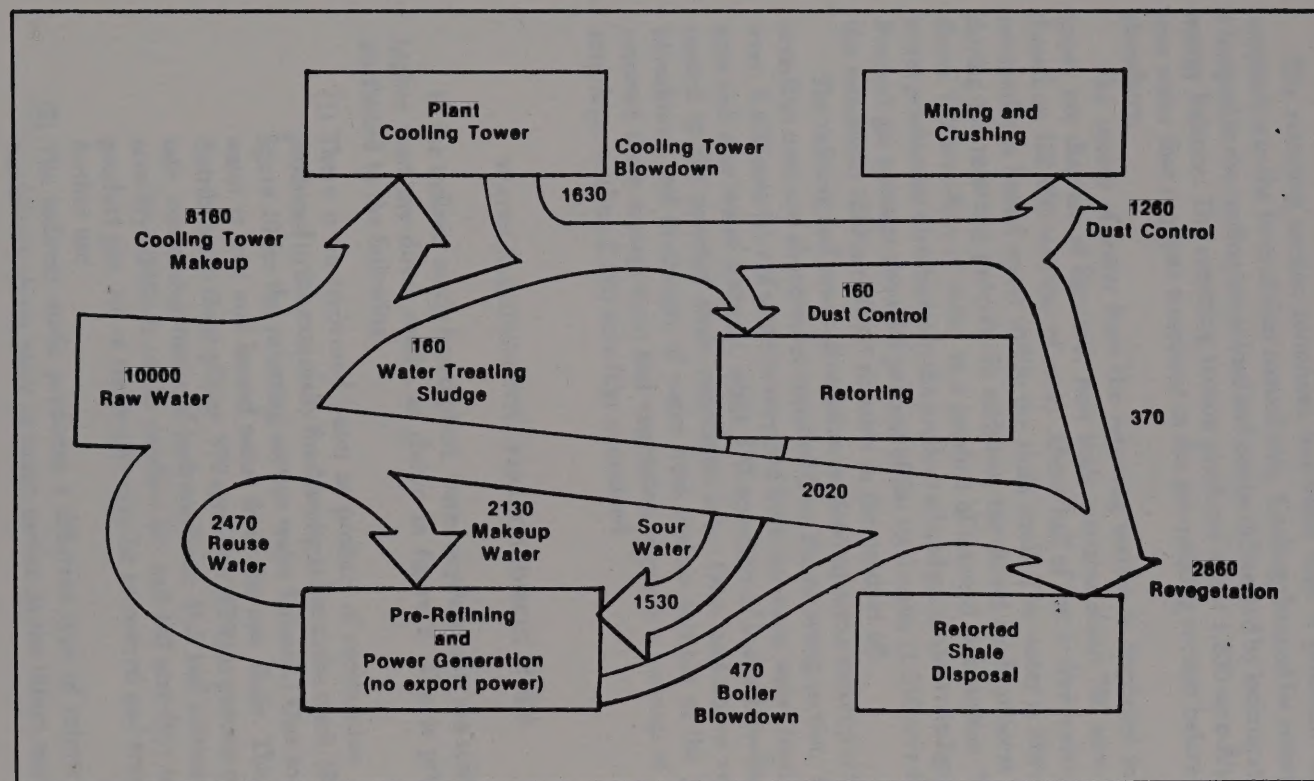


FIGURE 7.—Water requirements for a 100,000 BPD oil shale plant, Paraho direct mode retorting (acre-feet/year).

The retorting section consumes less water than it produces. Consumption is in the form of dust control only. Cooling demand for retorting is lumped in the cooling tower load and can be delineated by looking at the energy balance. The retorting section produces about 1,530 acre-ft/yr as sour water that requires treatment in the pre-refining section before use elsewhere.

The source of water from the retorting section is displayed in the upper pie diagram of figure 8. Raw shale contains about 780 acre-ft/yr (based on 152,000 tons/day of rock). About half of this is free water; the remainder is bound water within the shale itself. This water is liberated during the retorting process. In addition, the direct mode process produces 750 acre-ft/yr of water as a product of internal combustion. Total water production distributes in the product oil and gas as shown in figure 8. Product gas contains about 86 percent of the total water (1,310 acre-ft/yr); the remainder (220 acre-ft/yr) remains in the product oil.

The refining and power generation section requires a makeup of 2,310 acre-ft/yr over and above water supplied from the retorting section. However, 2,470 acre-ft/yr of water is recycled from the waste water treatment area and sour water stripper, while 470 acre-ft/yr of boiler blowdown is routed to the retorted shale vegetation area. Over and above various blowdowns and discharges of water from various sections of the plant, retorted shale management and vegetation requires a makeup of 2,020 acre-ft/yr, totaling 2,860 acre-ft/yr consumed.

WATER REQUIREMENTS—PARAHO INDIRECT MODE

In the indirect mode based plant, water requirements are somewhat higher than the direct mode, as shown in figure 9. This is primarily attributed to the following:

- (1) There is no recovered water as product of combustion. Water produced in the externally fired heater is lost to the stack. (Refer to figure 10 for the retorting section water balance.) One source of water is free and bound water from the raw shale. This water distributes in three places: 370 acre-ft/yr (47%) as process condensate, containing traces of hydrocarbons, H_2S and ammonia; 220 acre-ft/yr (28%) is in the product oil; and 190 acre-ft/yr is in the product gas. All of this water may be recovered and treated for further use.
- (2) The indirect mode produces a different type of retorted shale containing about twice as much carbon as the direct mode, thus

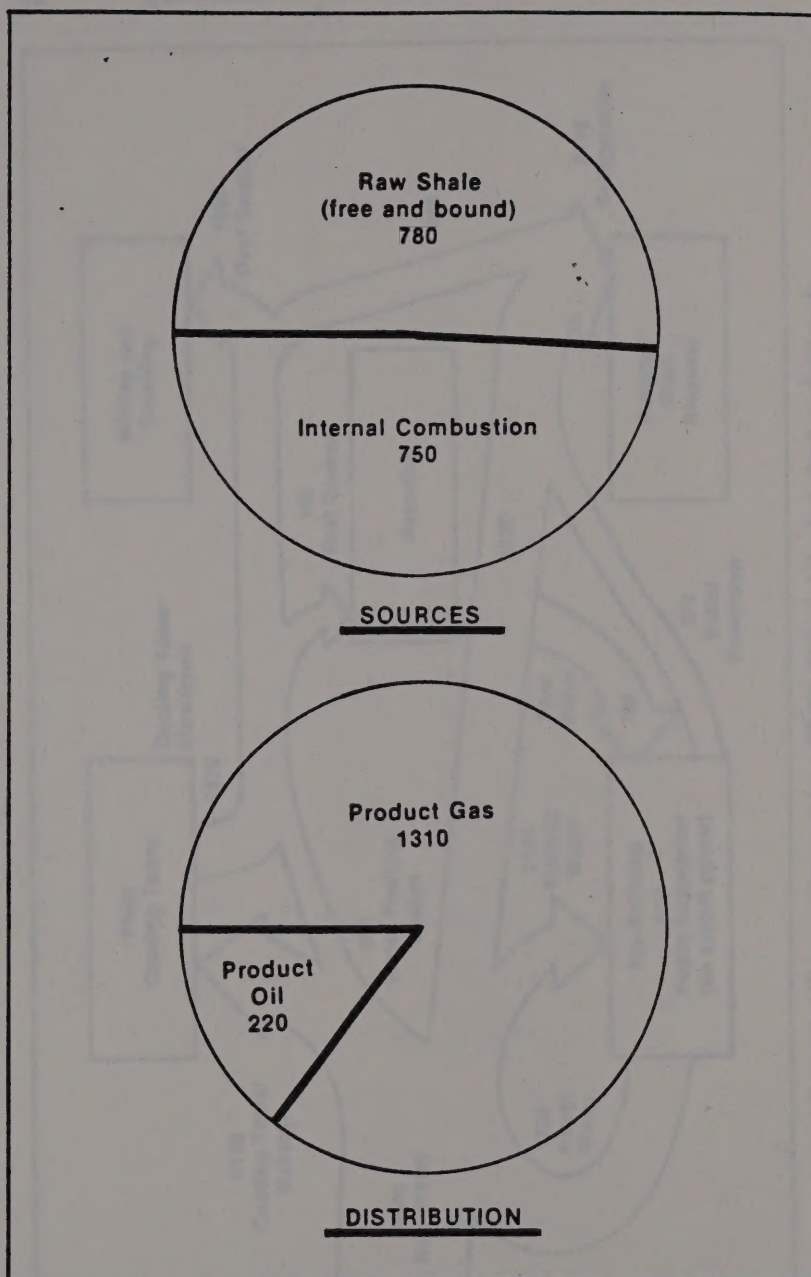


FIGURE 8.—Retort water balance, Paraho direct mode retorting (acre-feet/year).

Proportion of the 100,000,000



100,000,000



100,000,000

Proportion of the 100,000,000 population

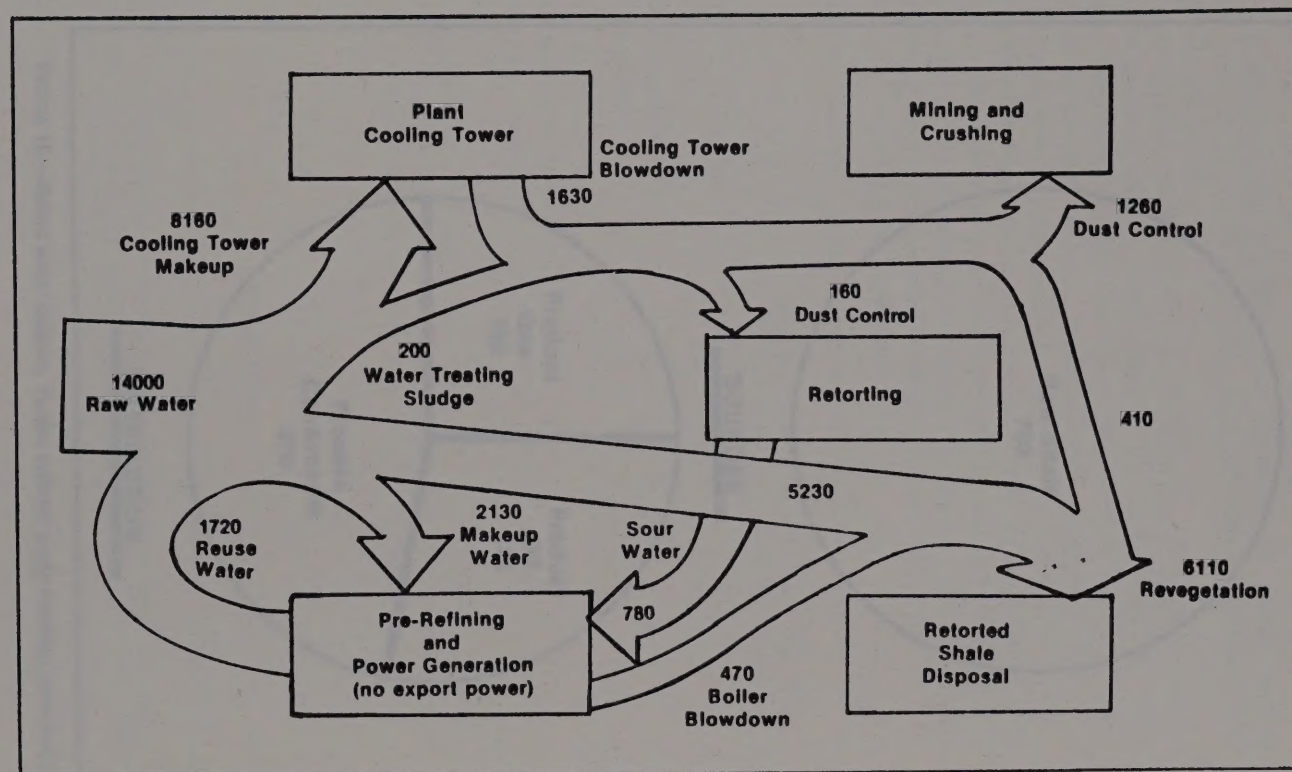


FIGURE 9.—Water requirements for a 100,000 BPD oil shale plant, Paraho indirect mode retorting (acre-feet/year).

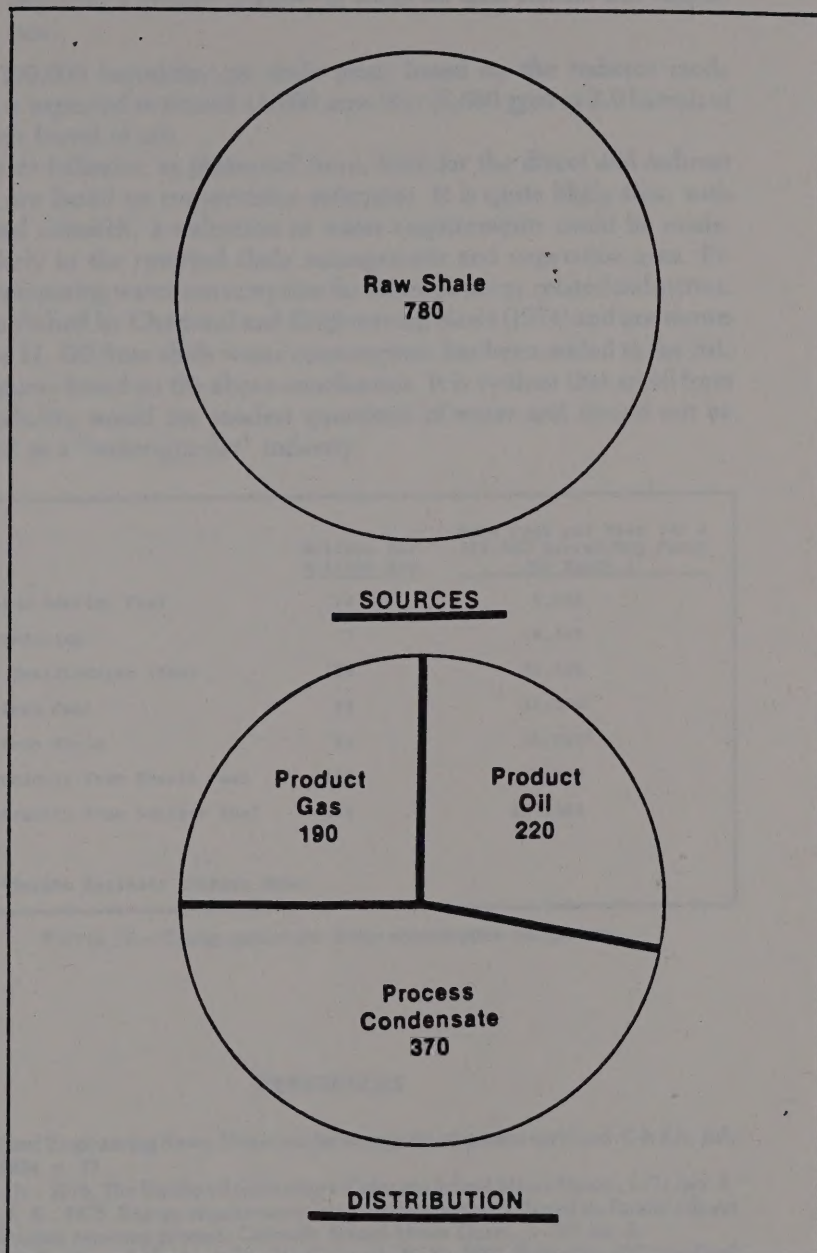


FIGURE 10.—Retort water balance, Paraho indirect mode retorting (acre-feet/year).

requiring a greater quantity of water for dust control and vegetation.

A 100,000 barrel/day oil shale plant based on the indirect mode process is expected to import 14,000 acre-ft/yr (8,680 gpm or 3.0 barrels of water per barrel of oil).

Water balances, as presented here, both for the direct and indirect modes, are based on conservative estimates. It is quite likely that, with additional research, a reduction in water requirements could be made, particularly in the retorted shale management and vegetation area. Figures, comparing water consumption for various energy related industries, were published by Chemical and Engineering News (1974) and are shown in figure 11. Oil from shale water consumption has been added to the list, using figures based on the above conclusions. It is evident that an oil from shale industry would use modest quantities of water and should not be classified as a "water-guzzler" industry.

	Gallons Per Million Btu	Acre Feet per Year for a 100,000 Barrel/Day Plant (Or Equiv.)
Uranium Reactor Fuel	14	9,400
Oil Refining	7	4,700
Coal Gasification (SNG)	58	39,000
Oil from Coal	50	34,000
Oil from Shale	24	10,000*
Electricity from Fossil Fuel	146	98,000
Electricity from Nuclear Fuel	234	157,000

*Paraho Estimate (Direct Mode)

FIGURE 11.—Energy processes: water consumption comparison.

REFERENCES

- Chemical and Engineering News, Water use for energy development surveyed: C & EN, July 22, 1974, p. 17.
- Jones, B., Jr., 1976, The Paraho oil shale retort: Colorado School Mines Quart., v. 71, no. 3.
- Kunchal, S. K., 1975, Energy requirements in an oil shale industry: based on Paraho's direct combustion retorting process: Colorado School Mines Quart., v. 70, no. 3.
- Stanfield, K. E., Frost, I. C., McAuley, W. S., Smith, H. N., 1951, Properties of Colorado oil shale: U.S. Bur. Mines R.I. 4825, figure 7.

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LONG RIDGE
EXPERIMENTAL SHALE OIL PLANT
MINED LAND RECLAMATION PERMIT APPLICATION

UNION OIL COMPANY OF CALIFORNIA

VOLUME II

March 1979

COPY NUMBER 34

the slopes above the bench site and the disposal areas. This natural runoff will then be channeled around the disposal areas and will enter the natural drainage of East and Middle Fork.

Precipitation falling on the bench site area will be collected and treated in an oil-water separator for removal of oily impurities and will be returned to the process water supply. A curbed area around the retort would contain the largest possible oil spill. Any spill would be discharged to the oil water separator, with the oil being returned to the liquid product treating section. If the capacity of the water retention and recycling system is exceeded, the excess water would flow into a catch basin and finally into a retorted shale drainage pond.

Since all ponds and ditches are designed for a 100-year, 30-min. storm condition and there will be no discharge of process water to surface waters, Union has concluded an NPDES permit is not required. Confirmation of this conclusion will be requested from the Colorado Department of Health, Water Pollution Control Division.

Discussion of the existing surface and ground water systems can be found in Appendices G-1 and G-2. Appendix G-4 presents a Water Quality Monitoring Program that will be implemented during plant operation.

Water Requirements

The estimated total water consumption by the project is 798 acre-feet per year. Water will be obtained from wells at an instantaneous rate of 550 gpm. The project water balance is shown in Figure G-1.

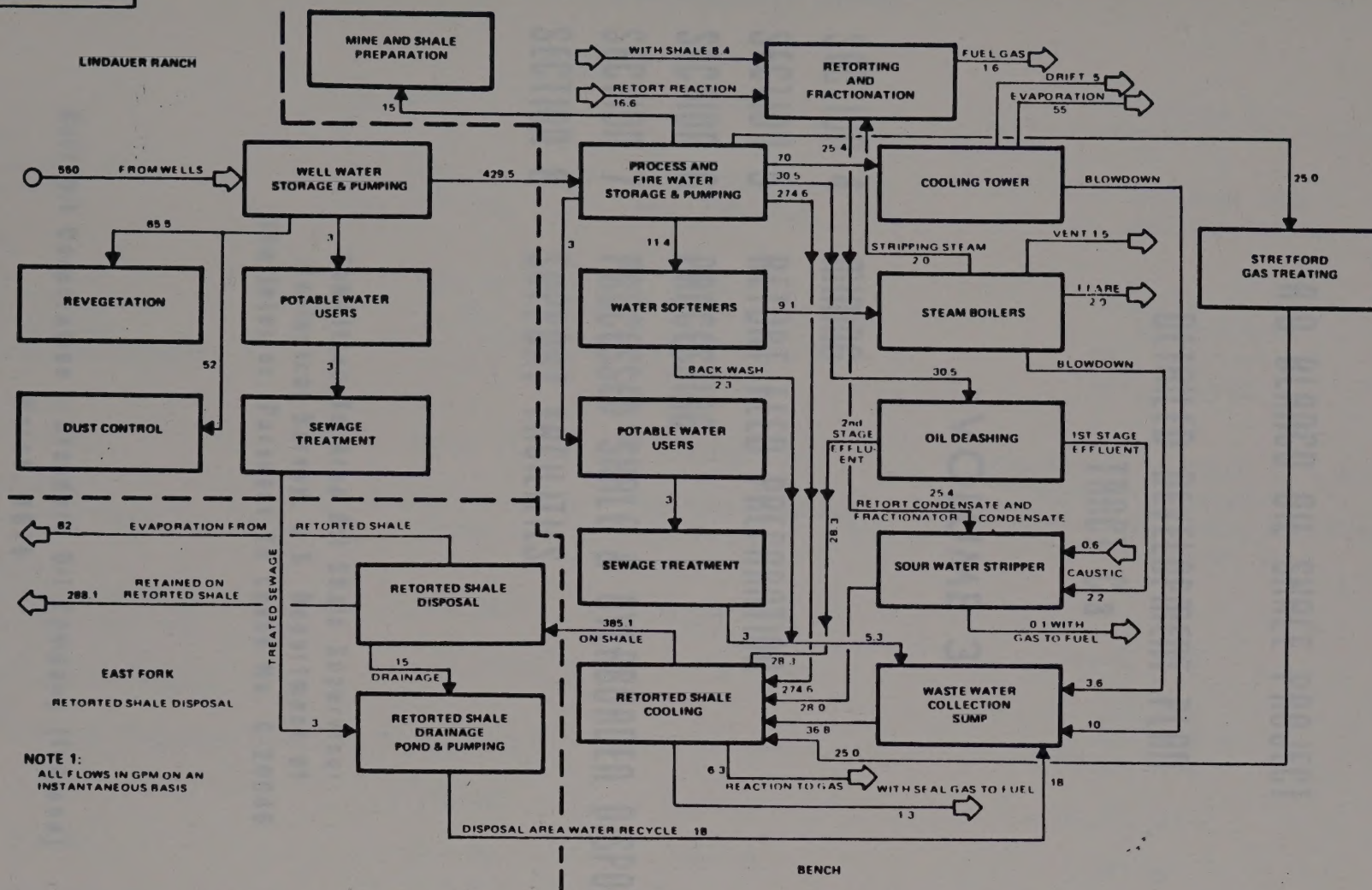


FIGURE G-1
MAXIMUM WATER SUPPLY AND USE

RIO BLANCO OIL SHALE PROJECT

DETAILED DEVELOPMENT PLAN TRACT C-a

VOLUME 3

- SECTION 4 MINING**
- SECTION 5 RETORT FEED PREPARATION**
- SECTION 6 PROCESSING**
- SECTION 7 PROCESSED SHALE & OVERBURDEN DISPOSAL**
- SECTION 8 SUPPORT FACILITIES**

**Submitted To Area Oil Shale Supervisor,
Geological Survey, U.S. Department of
the Interior; Pursuant To Lease No. C-20046**

**Gulf Oil Corporation - Standard Oil Company (Indiana)
March, 1976**

TABLE 1
RIO BLANCO PROJECT SUMMARY

	PHASE I		PHASE II
	Stage I	Stage 2	
TIMING			
Construction	Apr. 1977-Aug. 1979	July 1980-Aug. 1982	Aug. 1982-Aug. 1985
Operation	Aug. 1979-Aug. 1982	Aug. 1982-Aug. 1985	Aug. 1985 and beyond
MINING			
Type	Open Pit	Open Pit	Open Pit
Ore Production	10,700 TPSD	21,400 TPSD	119,000 TPSD
Ore Haulage	Belt Conveyor	Belt Conveyor	Belt Conveyor
Overburden Haulage	Truck	Truck	Belt Conveyor
PROCESSING			
Retorting	TOSCO II	TOSCO II	Combination of TOSCO II & Gas Combustion/Paraho
Upgrading	Thermal Cracking	Thermal Cracking	Delayed Coking & Hydrotreating
Processed Shale Haulage	Truck	Truck	Belt Conveyor
PRODUCTS			
Pipelineable Shale Oil	4,500 BPSD	9,000 BPSD	-
Upgraded Shale Oil	-	-	55,800 BPSD
Sulfur	11 LTPSD	22 LTPSD	153 LTPSD
Ammonia (anhydrous)	-	-	232 TPSD
Coke	-	-	467 TPSD
Moisturized Processed Shale	11,000 TPSD	22,000 TPSD	118,500 TPSD
WATER DEMAND	1,390 AFY	2,370 AFY	10,000 AFY
POWER DEMAND	17.7 MW	28.8 MW	227 MW
PEAK EMPLOYMENT			
Construction	700	400	2,200
Operation	300	500	1,100

4. Water Balance - The following summary describes the disposition of water involved in the normal operation of the Phase I - Stage 1 processing facility:

<u>Output</u>	<u>gpm</u>	<u>Acre-feet/year*</u>
Water on processed shale	251	365
Retort vent gas loss	357	520
Cooling tower loss	171	250
Miscellaneous loss	<u>17</u>	<u>25</u>
Total output	796	1160
<u>Input</u>		
Raw water intake	669	975
Free moisture on raw shale	27	40
Water produced in retorting	<u>100</u>	<u>145</u>
Total input	796	1160

*Based on 90% operating factor

The raw water intake is approximately 670 gpm, equivalent to about 975 acre-feet per year. An additional 130 gpm is available from the free moisture on raw shale and water produced in the retorting plant. Approximately 40% of the total water input is consumed in moisturizing processed shale. Evaporation losses from retorting and cooling tower operation use essentially all the remaining water input. Only a minor amount of water is chemically converted in the sulfur plant in producing elemental sulfur. The raw water requirement of the Phase I - Stage 1 processing facility will be supplied by mine dewatering operations and supplemental wells as required.

3.2 PHASE I PROCESSING EMISSIONS AND CONTROL - STAGE 1

This section identifies emission sources from the process plants of the Phase I - Stage 1 processing facility and describes pollution control techniques applied to these sources. The location of processing plants and stacks are shown on Figure 6-5-1.

Table 6-4-5

ESTIMATED PHASE II PROCESSING FACILITY COOLING WATER CIRCULATION

<u>Plant Description</u>	<u>Cooling Water Circulation, gpm</u>
TOSCO II Retorting	365
Gas Combustion Retorting	-
Raw Oil Recovery Plant	-
Delayed Coking Plant	235
Gas Oil Hydrotreating Plant	208
Naphtha Hydrotreating Plant	156
Hydrogen Plant	4,648
Oxygen Plant	8,438
High BTU Gas Plant	10,160
Low BTU Gas Plant	12,900
Foul Water Stripping Plant	6,090
Sulfur Recovery Plant	-
Ammonia Recovery Plant	6,350
Support Facilities	1,950
Tankage	-
Spent Water Collection System	-
Total Cooling Water Circulation	51,500

4. Water Balance - The following summary describes the disposition of water involved in the Phase II processing facility:

<u>Output</u>	<u>gpm</u>	<u>Acre-feet/year*</u>
Water on processed shale	2726	3950
Retort vent gas losses	1992	2900
Cooling water loss	1650	2400
Chemically converted	246	350
Miscellaneous	<u>34</u>	<u>50</u>
Total output	6648	9650
<u>Input</u>		
Raw water intake	5726	8300
Free water on raw shale	298	450
Water produced in retorting	<u>624</u>	<u>900</u>
Total input	6648	9650

*Based on operating factor of 90%

CHAPTER 5

WATER SUPPLY AND DISTRIBUTION

5.1 WATER DEMAND

Estimated water requirements for Phases I and II are given in Table 8-5-1.

Table 8-5-1
ESTIMATED MAXIMUM WATER REQUIREMENTS

	Acre feet per year		
	Phase I		Phase II
Use	Stage 1	Stage 2	
Processing	975	1,950	8,300
Potable	15	20	50
Irrigation	100	100	550
Dust Control	<u>300</u>	<u>300</u>	<u>1,100</u>
Total	1,390	2,370	10,000

About 70% to 80% of the estimated water demand is attributable to the processing facility. These requirements are defined in more detail in Section 6. but include water for boiler feed, moisturizing of processed shale, operation of retort scrubbers, and miscellaneous uses. Approximately 40% of the total process water input is consumed in moisturizing processed shale. Evaporation losses from TOSCO retort scrubbers and cooling towers account for almost all of the remaining water input; about 4% is chemically converted during processing in Phase II.

The potable water estimates given in Table 8-5-1 are based on a rate of 35 GPD per capita for operating personnel. Not included in the potable water estimate are those non-human potable needs in the processing facility, which are included in the processing estimate.

Irrigation requirements for revegetated areas (primarily the processed shale and overburden disposal pile) are particularly difficult to estimate because of unpredictable variations in natural precipitation from year to year. The estimates in Table 8-5-1 are based on the assumption that newly-revegetated areas would require irrigation at the rate of about nine inches per year.

This should provide adequate water for the dryer years and be more than enough for wet years.

Water requirements for dust control are also difficult to estimate because of variations in natural precipitation. The estimates given in Table 8-5-1 are adequate for several daily water applications during the warm, dry months of the year to some 10 miles of haul and access roads and other areas where dust control may be necessary. As noted above, water requirements for moisturizing processed shale are included in the processing facility estimate.

Expansion beyond the Phase II shale oil production level of 55,800 BPSD would require additional water at the rate of approximately 10,000 AFY per 50,000 BPSD of shale oil production. The water demand for a 300,000 BPD production level would require about 60,000 AFY.

5.2 WATER SUPPLY

The water supply for development of Tract C-a through Phase II will come from a mine dewatering system, supplemented as necessary by other ground water wells on the tract. Expansion beyond the Phase II production level of 55,800 BPSD will probably require the development of surface water supplies to augment Tract C-a ground water sources.

As now planned, the Phase I mine dewatering system will consist of eight wells lining the perimeter of the open pit. Maximum dewatering requirements in Phase I are projected to be about cubic feet per second. The Phase I project water requirements given in Table 8-5-1 are equivalent to approximately 1.9 and 3.3 cfs for Stage 1 and Stage 2, respectively. Thus, mine water alone will not be sufficient to meet Phase I demand and will have to be supplemented

February, 1977

WATER REQUIREMENTS FOR STEAM-ELECTRIC
POWER GENERATION AND SYNTHETIC FUEL PLANTS
IN THE WESTERN UNITED STATES

by

H. Gold, D.J. Goldstein, R. F. Probststein,
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Water Purification Associates
Cambridge, Massachusetts

A Subcontract Report to the University of Oklahoma
Science and Public Policy Program for:

Technology Assessment of Western Energy Resource Development

EPA Contract Number 68-01-1916

Project Officer
Steven E. Plotkin
Office of Energy, Minerals and Industry
Washington, D.C. 20460

Office of Energy, Minerals and Industry
Office of Research and Development
U.S. Environmental Protection Agency
Washington, D.C. 20460

Table 1-2. Summary of net annual water consumption and wet solid residuals generated at each site.

FACILITY	BEULAH, NORTH DAKOTA	COLSTRIP, MONTANA	GILLETTE, WYOMING	KAIPAROWITS/ ESCALANTE, UTAH	NAVAJO/ FARMINGTON, NEW MEXICO	RIPLE, COLORADO
SLURRY PIPELINE (25 x 10 ⁶ tons/yr @ 100% load factor) NET WATER CONSUMED - 10 ³ ACRE-FT/YR ^a WET SOLID RESIDUALS - 10 ⁶ TONS/YR			19.17 -			
LURGI (250 x 10 ⁶ scf/stream day @ 90% load factor) NET WATER CONSUMED - 10 ³ ACRE-FT/YR WET SOLID RESIDUALS - 10 ⁶ TONS/YR	3.31 1.20	4.62 1.27	4.21 0.72		5.64 3.00	
SYNTHANE (250 x 10 ⁶ scf/stream day @ 90% load factor) NET WATER CONSUMED - 10 ³ ACRE-FT/YR WET SOLID RESIDUALS - 10 ⁶ TONS/YR	7.67 1.08	7.81 1.12	7.78 0.71		8.67 2.84	
SYNTHOIL (100,000 bbl/stream day @ 90% load factor) NET WATER CONSUMED - 10 ³ ACRE-FT/YR WET SOLID RESIDUALS - 10 ⁶ TONS/YR	10.09 2.00	10.30 2.07	9.23 1.23		11.75 5.31	
ELECTRICAL GENERATION (3,000 MWe @ 35% eff, 70% load factor) NET WATER CONSUMED - 10 ³ ACRE-FT/YR WET SOLID RESIDUALS - 10 ⁶ TONS/YR	23.88 2.65	26.66 3.01	25.84 1.32	29.82 5.30	29.21 5.00	
ELECTRICAL GENERATION (1,000 MWe @ 35% eff, 70% load factor) NET WATER CONSUMED - 10 ³ ACRE-FT/YR WET SOLID RESIDUALS - 10 ⁶ TONS/YR						9.49 0.38
OIL SHALE (50,000 bbl/stream day @ 90% load factor) NET WATER CONSUMED - 10 ³ ACRE-FT/YR WET SOLID RESIDUALS - 10 ⁶ TONS/YR						6.48 20.40
OIL SHALE (100,000 bbl/stream day @ 90% load factor) NET WATER CONSUMED - 10 ³ ACRE-FT/YR WET SOLID RESIDUALS - 10 ⁶ TONS/YR						12.92 40.81

^aTo convert 10³ acre-ft/yr to 10⁶ tons/yr multiply by 1.36,
to convert 10³ acre-ft/yr to 10⁶ gal/day multiply by 0.894.

3. SHALE CONVERSION

3.1 Underground Mining and Surface Processing

The analysis of shale conversion in the present assessment is restricted to the TOSCO II process by the program guidelines. In the TOSCO II process the oil shale is mined underground and then processed on the surface. The surface processing operation involves crushing the shale and then heating (retorting) it to produce the shale oil. The retorted shale oil is too viscous to be piped, and too high in nitrogen and sulfur to be used as normal refinery feedstock so that it must also be put through a refinery upgrading process, normally by hydrocracking. In addition, it is necessary to dispose of the spent shale from the retorting, equal to about 80 to 85 percent by weight of the originally mined shale with a volume before compaction averaging 50 percent greater than its in-place volume, and even after maximum compaction at least 12 percent greater.

The water requirements for the mining and crushing of the raw shale will be considered in Section 7 along with the same requirements for coal, since the operations are quite the same as in the underground mining of coal, and differ only in some details and in the quantities handled. Similarly the water requirements for spent shale disposal will be considered in Section 8, along with the water requirements for the solids and ash disposal in the coal conversion processes. In this same section evaporation losses, plant dust control and service and potable water needs will also be evaluated, since they too agree in kind with those for the coal conversion processes.

It will be assumed that needed auxiliary electric power will be purchased and not generated onsite. This is consistent with the TOSCO II

design in which the process steam needed in the plant is generated by burning fuel gas generated in the shale conversion.

3.2 TOSCO II Process

In the TOSCO II retorting scheme¹ shown schematically in Fig. 3-1, crushed shale of minus 1/2 inch size is preheated by pneumatically conveying the shale upward through a vertical pipe concurrently with hot flue gases from the ball heater. The flue gas is cooled during this process and the cooled gas is passed through a venturi wet scrubber to remove shale dust before venting to the atmosphere at a temperature of about 125 to 130° F.

The ball heater is a vertical furnace whose purpose is to heat up ceramic balls of about a 1/2 inch in diameter. After the balls are heated they are fed along with the preheated shale, which has been separated from the flue gas in settling chambers and cyclones, into a horizontal rotating kiln where the pressure is slightly above atmospheric. The mixture of balls and shale flows through the kiln and the shale is brought to a retorting temperature of about 900° F through conductive and radiative heat exchange with the balls. The resulting hydrocarbon and water vapors are drawn off and fractionated leaving behind a mixture of balls and processed shale.

The ceramic balls are size-separated from the spent shale, which is a fine powder, by passage through a trommel (a heavy duty rotating cylinder with many small holes punched in its shell). Warm flue gas is used to remove residual dust from the ball circulation system. The dust is removed from the flue gas with a venturi wet scrubber. The balls are then circulated back to the ball heater, by means of a bucket elevator, for reheating by burning some of the product gas.

higher heating value gas is used as feed material for the production of the hydrogen needed in the upgrading. Before the retort gas is burned hydrogen sulfide would be removed with subsequent sulfur recovery. Ammonia will be separated out and recovered as a liquid from the sour water produced in the hydrotreating, while the sulfur will be recovered from the hydrogen sulfide which is drawn off as a gas. The upgrading and cleaning process described for the TOSCO II refinery resembles standard refinery processing procedure.

3.3 Water Streams for Retorting

In this section, we consider the retort water streams for the specific conceptual design discussed in Ref. 1 of a plant retorting 35 gallon per ton shale with a 50,000 bbl per stream day output of upgraded shale oil. On Fig. 3-1, reproduced from Ref. 1 with some small changes, we have summarized our derived values of the water streams, with all figures in gallons per stream minute (gpm). To obtain the corresponding streams for a 100,000 bbl/day plant, it is sufficient to simply double all the input and output figures. The water quantities shown in Fig. 3-1 were derived from the water flow chart of Fig. 3-3, which was taken from Ref. 1 and to which some clarifications were added.* It is not completely straightforward to distinguish the retorting and upgrading streams in Fig. 3-3. Moreover, of particular importance in the TOSCO process is the feature noted earlier that the wastewater fed into the moisturizer which is not vaporized is sealed into the processed shale.

It can be seen from Fig. 3-3 that the only specifically noted water addition to the retorting step is the 90 gpm leaving the crusher dust suppression unit that is added to the raw shale. All of the other dust suppression

* Personal communications with TOSCO personnel.

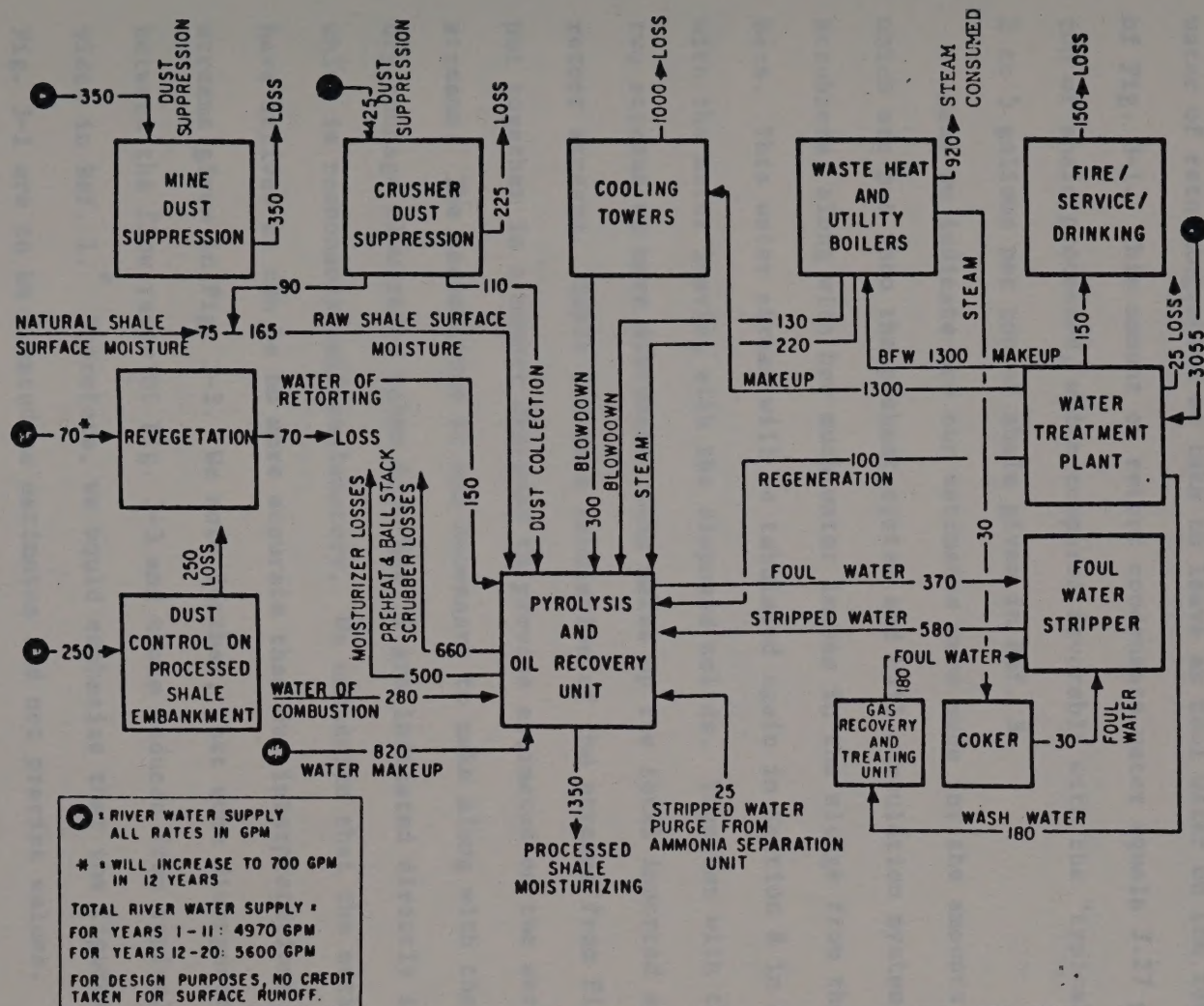


Fig. 3-3. TOSCO II process water streams for upgrading shale oil output of 50,000 bbl per stream day with feed of 35 gallon per ton oil shale⁶.

water totaling 110 gpm is sent directly to the moisturizer. The only water noted to be specifically coming out of the retorting is 150 gpm listed as water of retorting, which we take to leave as foul water on the retorting diagram of Fig. 3-1. This amount of retort condensate water equals 3.27 gallons per ton of shale processed, which compares favorably with the "typical" value of 2 to 5 gallons per ton of shale given in Ref. 3.

Next we indicate how our estimates were made for the amounts of water which are put into the preheat system and ball circulation system stack gas scrubbers, along with how much water leaves in the sludge from these scrubbers. This water stream will be tabulated again in Section 8 in connection with the water leaving with the disposed solids. Together with the previous two streams we have discussed, this makes up the total imported and exported retort streams. Table 3-1 is a tabulation of the streams from Fig. 3-3 put together in a manner designed to provide estimates on the scrubber streams. The assumptions it was necessary to make along with the various dry tonnage flow rates taken from Ref. 1 are indicated directly in the table, which is reasonably self-explanatory. We emphasize that the estimates we have arrived at can be no more accurate than our interpretations of the streams given in Fig. 3-3. We note further, that some divergences do exist between the flow rates of Fig. 3-3 and those deduced from typical data provided in Ref. 1.* Therefore, we would emphasize that the figures given in Fig. 3-1 are to be treated as estimates and not precise values.

We have shown on Fig. 3-1 the stream flows we deduced that are associated with the moisturizer unit. We do not consider the water leaving with the spent shale chargeable to the retort section, but rather we treat this stream as part of the spent shale disposal system and as such we will discuss it in Section 8.

* For example, Tables 3 and 21.

Table 3-1. Determination of TOSCO II retort water streams for upgrading shale oil output of 50,000 bbl per stream day with feed of 35 gallon per ton shale, on basis of water balance for combined retorting and upgrading steps 1.

	Individual gpm	Total gpm	Makeup gpm
<u>Water out in cumulative sludge from scrubbers</u>		100	
Water in to processed shale moisturizing from retorting and upgrading	1,350		
Moisture out in processed shale (.14 x 53,625 tpd)	<u>(1,250)</u>		
	100		
<u>Vapor out in preheat and ball circulation stacks</u>		660	
Assumed sources of vapor in stacks:			
Water of combustion	280		
Natural shale surface moisture	75		
Moisture on shale from dust suppression	90		
Makeup water	<u>215</u>		
	660		
<u>Water in to preheat and ball circulation scrubbers</u>		310	310
Makeup water (from vapor calculation)	215		
Sludge water* ([.38/.62][925] tpd)	<u>95</u>		
	310		
<u>Water in to moisturizer scrubber</u>		15	15
Makeup water (same ratio to sludge as above)	10		
Sludge water* ([.38/.62] 43 tpd)	<u>5</u>		
	15		

* Total clarifier sludge equals 968 tpd (925 tpd from preheat and ball circulation scrubbers plus 43 tpd from moisturizer scrubber), while net water in the cumulative sludge equals 100 gpm or 600 tpd. Solids therefore represent 62% of sludge. Approximate split shown in Fig. 3-1 between preheat and ball circulation scrubbers is based on same relative ratios of water to dry solids.

Table 3-1 (continued)

	Individual gpm	Total gpm	Makeup gpm
<u>Water in to moisturizer</u>		1,740	
Moisture out in processed shale	1,250		
Water out in moisturizer scrubber sludge	5		
Vapor out in moisturizer stack	500		
Water in to moisturizer scrubber	<u>(15)</u>		
	1,740		
Assumed sources of water in to moisturizer:			
Cooling tower blowdown	300		
Utility boiler blowdown	130		
Regenerant wastes from deionizer	100		
Dust collection	110		
Stripped water	580		
Stripped water from ammonia unit	25		
Makeup water	<u>495</u>		495
	1,740		
<u>Foul water out of pyrolysis and upgrading</u>		370	
Water of retorting	150		
Steam used in upgrading	<u>220</u>		
Total assumed to leave as foul water	370		
			<u>820</u>
Total water makeup from river			820

The 95 gpm of water in the effluent sludge from the preheat and ball circulation scrubbers, when added to the 150 gpm retort effluent condensate, constitutes the exported water stream. The influent streams to the scrubbers of 310 gpm plus the 90 gpm put into the raw shale feed makes up the imported stream which is seen to amount to about half of the 820 gpm makeup water.

3.4 Water Streams for Upgrading

From Fig. 3-2 it is seen that the major operations of the upgrading process are fractionation, delayed coking, hydrotreating, and gas cleanup and recovery. It is evident that the major water needs in such a system are the cooling waters required for the fractionator and coker and the water required for the production of hydrogen by steam reforming. The principal effluents will be the cooling tower and boiler blowdowns and the sour water generated in the hydrotreating and gas treating units.

In evaluating the water streams from the overall flow diagram of Fig. 3-3, the quantity most difficult to determine is the amount of steam consumed in the hydrogen plant. In Fig. 3-3, there is 920 gpm shown as steam consumed. As an upper limit we can assume that all of this amount represents steam consumption in the hydrogen plant. An alternate estimate obtained from steam usage figures* is 279,000 lb/hr or 558 gpm. Table 3-2, which is a compilation of the influent and effluent streams for the refining operation, lists both figures. We have carried out a water equivalent hydrogen balance for upgrading shale oil and find a minimum net consumption of about 40 lb H₂O/ton of shale or somewhat less than half of the lower of the two figures. This makes the 558 gpm figure the more probable value.

All of the stream quantities shown in Table 3-2 are self-explanatory and for the most part have been taken directly from Fig. 3-3. The exception is the 220 gpm of steam, which was assumed in our retort calculation to be used in the upgrading and to be converted to foul water (cf. Table 3-1). We would note here, that we have carried out an approximate overall heat balance for the TOSCO II retorting and upgrading process. The raw shale

* Fig. 38, p. 151, Ref. 1.

was taken to have a heating value of 3,070 Btu/lb⁴. The net output of materials of significant heating value not used in the 50,000 bbl/day plant was taken to be 47,000 bbl/day of fuel oil, 4,330 bbl/day of liquified petroleum gas and 800 tons/day of coke¹. In addition, about 5% of the heating value of the shale was assumed to be unused, consistent with the amount of carbonaceous residue that remains with the spent shale in the TOSCO process.

Table 3-2. Compilation of TOSCO II refinery water streams for upgraded shale oil output of 50,000 bbl per stream day with feed of 35 gallon per ton shale, on basis of water balance for combined retorting and upgrading steps.

	<u>gpm</u>
<u>Imported</u>	
Steam used in upgrading	220
Wash water to gas treating unit	180
Steam to coker	30
Cooling tower makeup	1,300
Steam consumed in hydrogen plant	558 - 920
Total	2,288 - 2,650
<u>Exported</u>	
Foul water converted from steam used in upgrading	220
Foul water out of gas treating unit	180
Foul water out of coker	30
Cooling tower blowdown	300
Boiler blowdown	130
Total	860

Assuming 1,200 Btu removed per pound of water evaporated, it was found that the 1,000 gpm of water evaporated in the cooling tower corresponds to a heat loss of about 20 to 25% of the total heat dissipated in the plant. The upper limit assumes additional unaccounted losses of about 5%. This would indicate a well designed cooling system that is probably not too far off optimum.

3.5 Process and Cooling Water Consumption

From the water stream quantities detailed in the preceding two sections, the net process and cooling water consumption for the TOSCO II plants can be specified in a format consistent with that for the coal conversion processes.

The net consumption of retort water associated with a 50,000 bbl per stream day plant can be determined from Table 3-1. The retort water consumption is made up of the 215 gpm of makeup water and 90 gpm of dust suppression water leaving in the preheat and ball circulation stacks plus the net of 490 gpm leaving as vapor out the moisturizer stack. The net consumption is therefore 795 gallons per stream minute or 716 gallons per calendar minute with a 90% load factor. Although the vapor leaving in the moisturizer stack is charged to the retort, the processed shale moisture and scrubber sludge waters are charged to solids disposal and as such are considered in Section 8.

From Table 3-2 the net water consumption in the refining is seen to range between 428 and 790 gpm, after subtracting the 1,000 gpm evaporated in the cooling towers. From our discussion in Section 3.4 the lower value is the more probable one but we have taken the average of 609 gallons per stream minute to ensure the presentation of a conservative water consumption estimate. With a 90% load factor this corresponds to 548 gallons per calendar minute.

We have already discussed in Section 3.4 the evaporated cooling water rate of 1,000 gpm. We assume that this figure also includes the drift and leakage losses. For consistency with our own detailed cooling calculations the drift and leakage losses are taken at 3% of the amount evaporated. In that case, at a 90% load factor we would have a total of 900 gallons per calendar minute lost in the cooling towers with 845 gpm evaporated and 26 gpm lost to drift and leakage.

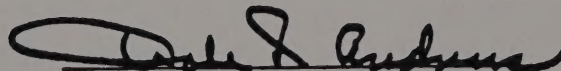
As noted earlier the corresponding water rates for a nominal 100,000 bbl/day plant are obtained by doubling the rates discussed.

References

1. Colony Development Operation, "An Environmental Impact Analysis for a Shale Oil Complex at Parachute Creek, Colorado, Part 1 - Plant Complex and Service Corridor," Atlantic Richfield Company, Denver, Colorado, 1974.
2. Merycalf & Eddy Engineers, "Water Pollution Potential from Surface Disposal of Processed Oil Shale from the TOSCO II Process," Vol. I, a report to Colony Development Operation, Atlantic Richfield Co., Operator, October 1975.
3. U.S. Department of the Interior, "Final Environmental Statement for the Prototype Oil Shale Leasing Program," Vol. I, U.S. Gov't. Printing Office, Washington, D.C., 1973.
4. Hendrickson, T.A. (editor), Synthetic Fuels Data Handbook, p. 30, Cameron Engineers, Inc., Denver, Colorado, 1975.

**DRAFT
ENVIRONMENTAL STATEMENT**

**PROPOSED
SUPERIOR OIL COMPANY
LAND EXCHANGE
AND
OIL SHALE RESOURCE
DEVELOPMENT**


STATE DIRECTOR, COLORADO STATE OFFICE

**U. S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT**

SUMMARY

(X) Draft () Final Environmental Statement

Department of the Interior, Bureau of Land Management

1. *Type of Action:* (X) Administrative () Legislative

2. *Brief Description of Action:* The Superior Oil Company requested an exchange of public land for private land. With the exchange, an economical mining unit would be formed and oil shale resources developed. Major federal actions would be the revoking of the oil shale withdrawal by the Secretary of the Interior and the exchange of land by BLM.

Following the exchange, Superior would construct an underground mine and a processing plant. The mine would produce an average of about 26,000 tons of oil shale daily. From the oil shale, the plant would produce about 4,800 tons of nahcolite, 11,500 barrels of shale oil, 580 tons of alumina, and 1,000 tons of soda ash daily. Production would continue for about 20 years. Above-ground facilities would occupy about 380 acres. Approximately 920 people would be employed during operation of the project. Products would be hauled from the plant by truck.

3. *Summary of Environmental Impacts:* Jobs would be created and the average income of the area increased. Other industries, such as agriculture, would be disrupted by the drawing away of employees to the new employments. Businesses would prosper and the costs of goods and services would be inflated. Overall, the quality of life would increase. However, those on fixed incomes and those unable to compete in business would have their quality of life decreased. Completion of the project and the

migration of some of the people out of the area would depress the area.

Lifestyles would be further trended from an agricultural-type, or rural, to industrial. Only Rio Blanco County and the Meeker School District would collect sufficient revenues to cover costs of community services to the new population. Service levels would decline or taxation would increase in Garfield County, Rifle, Rangely, Meeker, and in the Rifle and Rangely School Districts.

Two ranching operations would be impacted by reducing net revenues. Either the ranchers would be forced from business or the operation would be further subsidized.

Highway usage would expand. Maintenance costs would be higher. Congestion would increase as would safety hazards, noise levels, and deer-vehicle collisions.

Water quality in Piceance Creek and the White River would be increased by the removal of salt during operation of the project. The quality of other valued elements of the environment, such as air quality, would decline.

4. *Alternatives Considered:*

A. No Action

B. Product Transportation

1. Railroad

2. Pipeline

C. Expanded Resource Development

5. *Request for Comments:* See the list contained in Chapter 9--Consultation and Coordination.

Project Operation

Auxiliary Facilities

ELECTRICAL SYSTEM

The maximum requirement for electrical power would occur during operation of the project. During this time, an average of approximately 738,000 kilowatt hours of electricity would be used daily.

POTABLE WATER SYSTEM

Condensed water from the soda ash and alumina processing units would supply the average daily requirement of about 50,000 gallons (Figure 1-10). The water would be pumped to the domestic water treatment plant, treated, and piped to the domestic water storage tank. Water would then be gravity fed to the plant for use and to the mine area for storage and use.

SEWAGE TREATMENT SYSTEM

The sewage treatment system would produce a total of about 0.4 million gallons of treated effluent and 2.5 tons of sludge daily (Figure 1-11). The treated effluent includes precipitation and about 9,000 gallons daily, every day of the year, pumped from the White River through the fire loop to test that system. The water from testing the fire loop would be collected and routed to the industrial waste treatment plant by a storm sewer system. Until construction is complete on the process water storage basin, effluent would be hauled to the existing sewage treatment plant at Meeker, Colorado. From then on, effluents would be piped to the process water storage basin for reuse in the processing units. Sludge would be trucked to the shale storage area where it would be placed on the overland conveyor for backfilling of the mine.

Mine

Mining would occur on three levels within the mining zone (Figure 1-12); the lower level contains nahcolite-rich oil shale, the middle level is dawsonite-rich, and the upper level contains both minerals in mineable quantities. Production would vary between levels to accommodate market demand for the different products. The three levels would be developed in superimposed panels designed to follow the average natural inclination, or deviation from horizontal, of the mine zone which is about 14 degrees.

Panels would be about 100 acres in size with about 100-foot thick barrier pillars separating the panels (Figure 1-13). Along with the barrier walls, pillars would be left within the panel for structural strength. The distance between pillars would be between 45 and 60 feet. If unexpected conditions

occurred, such as structural failure or excessive water, the panel would be sealed off and bypassed without disrupting work in other panels. Panel mining would also allow processed shale to be backfilled in the mine simultaneously with mine production.

Blasted shale would be conveyed to the primary crusher where it would be sized to less than 8 inches. The crushed shale would be transported by the overland conveyor to the secondary crusher where it would be crushed to less than 3 inches.

Initial production mining would be restricted to the lower level where testing and proving of mining techniques would occur along with the production and marketing of nahcolite. About 9,400 tons of nahcolite-rich oil shale would be produced daily for a total of about 4,422,000 tons over the 2-year period of nahcolite only production. Approximately 3,350 tons daily of nahcolite product would be separated and 6,050 tons of nahcolite-stripped shale, including fine materials from crushing, conveyed to the shale and process water storage area. In addition, about 1,950 tons per day would go directly to the shale storage area from the secondary crusher as a result of construction of the No. 2 and No. 3 adits and access ramps connecting the upper and middle zones to the lower zone during premining. This shale would be removed and stored in the shale storage area to provide working space in the mine and allow ultimate processing and recovery of minerals.

An average of approximately 26,175 tons daily would be mined during full scale production (Figure 1-14). The nahcolitic and non-nahcolitic oil shales would be kept separated through the underground primary crushers, overland conveyors, and secondary crushers at the nahcolite recovery unit.

Plant

SHALE AND PROCESS WATER STORAGE AREA

Shale Storage Area

An average, over about 3 years, of approximately 13,000 tons-per-day of shale would be conveyed to the shale storage area from the secondary crushers until full scale operation (Figure 1-15). An initial stockpile of about 14 million tons would be built up over about 3 years. This stockpile would be about 80 acres in size and about 80 feet high; roughly even with the plant site terrace. During the following 5 years a portion of the shale in the stockpile would be conveyed to the oil recovery unit for processing. After this time the stockpile would be reduced in size to about 5.5 million tons and maintained for about 18 years. The stockpile would then be depleted by the end of project operations.

Process Water Storage Basin

About 4.4 million gallons daily would be pumped from the water storage basin to the process water system (Figure 1-16). This quantity equates to an average of about 3,055 gallons per minute pumped. From the mine, about 1.4 million gallons per day would be pumped into the basin, while another 1.0 million gallons would come from the dewatering of process shale in the shale storage area, and another 0.4 million gallons from the sewage treatment system. The remaining quantity of about 1.6 million gallons needed to balance inflow and outflow from the basin would be withdrawn from the reinjection wells.

PROCESS WATER SYSTEM*Cooling Water System*

Except for the 118,000 gallons that would go to the water treatment plant, the approximately 4.4 million gallons of water daily that would be pumped from the process water storage basin would go to the cooling tower (Figure 1-17). This water would be combined with about 34.7 million gallons per day recycled from the processing units. After being cooled to 80 degrees F, about 25.6 million gallons per day would be pumped to the soda ash and alumina processing units and about 8.7 million gallons would go to the oil recovery unit. About 3.4 million gallons would be piped to the process water treatment plant as continuous blowdown. About 1.5 million gallons per day would be evaporated.

Steam Plant

Water for the steam plant would come from recycling within the essentially closed system that would require only nominal make up water. High pressure steam, about 5,900 tons per day, would be piped to the processing units to drive power turbines (Figure 1-18). Low pressure steam out of the units would be piped throughout the plant for process and oil storage heating. Approximately 1.4 million gallons of water per day would be returned to the steam plant.

Process Water Treatment Plant

Approximately 118,000 gallons per day of water pumped from the process water storage basin and 3.4 million gallons from the cooling water system would supply the treatment plant (Figure 1-19). 3.4 million gallons of the treated water would be piped to the soda ash and alumina processing units. Another approximately 118,000 gallons would be evaporated from the treatment facility. A ton of lime would be required daily for the plant. Sludge, about one ton per day, would be transported from

the plant to the shale storage area for backfilling into the mine.

PROCESSING UNITS*Nahcolite Recovery Unit*

During full scale operation over 12,300 tons per day of nahcolitic oil shale would be conveyed from the secondary crusher to the nahcolite unit (Figure 1-20). When necessary to balance output of the mine and the capacity, or thruput, of the processing unit, shale containing nahcolite would be temporarily deposited in or withdrawn from the storage dome. During processing about 5 percent of the nahcolite would be lost as fine dust collected in baghouses and 15 percent would remain in the oil shale and later recovered as soda ash. The average daily production of about 4,800 tons, consisting of 80 percent nahcolite and 20 percent residual oil shale by weight, would be conveyed to the nahcolite silos for shipment.

Purchasers of the nahcolite would load their trucks at the storage silos for shipment to the points of consumption. Since nahcolite is readily dissolved in water, the trucks would be sealed.

Oil Recovery Unit

From the secondary crushers, nahcolite recovery unit, and shale storage area, about 20,000 tons per day of oil shale would be fed on the grate of the retort (Figure 1-21). The shale would travel through three zones within the unit; the retorting, cooling, and air heating zones.

In the retort zone, indirect burners would heat a gas stream that would be passed through the shale bed. Kerogen, the substance in the oil shale that yields the shale oil, would be decomposed and carried as an oil mist by circulating gas to an oil removal system. The system would consist of a conditioner and electrostatic precipitator. In the conditioner the mist would be forced to form droplets consisting of a mixture of oil and water. The precipitator would then remove the droplets from the gas by electrostatic charging and subsequent precipitation onto a collector in a strong electric field.

The oil and water mixture would go to a separation tank. From the top of the tank about 11,500 barrels of oil daily would be removed and piped to the oil storage tanks. Superior would then truck the shale oil to Rangely, Colorado, for transport in existing pipelines. Approximately 180,000 gallons per day of water would be removed from the bottom of the tank, pumped to the shale storage area, and used to wet the processed shale as it would be placed on the overland conveyors for mine backfilling.

Process gas separated in the oil removal system would be used in the retort burners, inert gas gen-

erator, and other plant facilities, including the steam plant. Gas from the inert gas generator, which would contain less than one percent oxygen, would be introduced into the retort where the oil shale would enter and, as a result, seal, or prevent, gas emissions. Within the unit, this heated gas would be used in the retort zone to dilute the burner, thereby controlling temperatures and used as the circulating gas, or carrier, for the oil mist.

In the air heating zone heat from the retorted oil shale is further recovered by passing air through the bed. The air is then used in the retort zone burners to increase combustion efficiency and in the nahcolite and soda ash and alumina recovery units.

Retorted shale would be discharged from the unit through a mechanical air seal and conveyed to the soda ash and alumina recovery units.

Soda Ash and Alumina Recovery Units

About 15,600 tons of retorted shale would be conveyed daily from the oil recovery unit to the soda ash and alumina units where it would first be crushed to increase leaching efficiency (Figure 1-22). The shale would be mixed with a leaching solution to dissolve the minerals. The approximately 3.4 million gallons daily of water from the process water treatment plant would serve to make up water lost from the leaching solution. The dissolved minerals and the solution would be physically separated from the shale and transported to crystallizers for removal of the minerals. Washed, or leached, for a second time to further remove minerals, the processed shale would be conveyed to the shale storage area for backfilling in the mine.

Following crystallization, the soda ash (Na_2CO_3) and aluminum hydroxide ($\text{Al}(\text{OH})_3$) crystals would be washed and kiln dried, or calcined. Along with drying the products, calcining would also change the aluminum hydroxide to alumina (Al_2O_3). Approximately 580 tons per day of alumina and 1,000 tons of soda ash would be produced and conveyed to storage silos. Of the quantity of soda ash produced, about 43 percent would be derived from residual nahcolite in the oil shale and 57 percent from the dawsonite. Superior would truck the soda ash and alumina in sealed trailers to the proposed storage facilities at Rifle, Colorado, for ultimate rail shipment.

In the crystallization process about 270,000 gallons of water would be vaporized or distilled. The vapor would be condensed by water from the cooling water system. About 50,000 gallons of the distilled water would be piped to the domestic water treatment plant, chlorinated, and used for potable water requirements. The remaining 220,000 gallons would be piped to the process water storage basin.

BACKFILLING

Processed shale, sludge, and collected dust would be backfilled in the mine to avoid surface disposal and help retard degradation of the mine pillars. From the soda ash and alumina processing units, approximately 13,950 tons of processed shale wetted with about 1.8 million gallons of water from the units would be conveyed to the shale storage area (Figure 1-23). Over a 3-day temporary storage period about one-half of the water would drain into the process water storage basin.

The processed shale, along with about 2.5 tons of sludge from the sewage treatment facilities, 1 ton of lime sludge from the process water treatment plant, 127 tons of dust collected in baghouses, and 1,100 tons of dust from crushing and screening operations, would be placed on the underside of the overland conveyor daily. Before being conveyed to the mine, the mixture would be wetted with about 180,000 gallons of water daily from the oil and water separation tank associated with the oil recovery unit. Another 3.6 million gallons of mine water would be added in the slurry plant within the mine to bring the moisture content to about 50 percent.

The slurry plant would be installed at the end of the No. 1 adit on the lower mine level. The backfilling system would also include pumps, about 80,000 feet of pipe, and other electrical distribution and control equipment. The slurry would be piped, at a rate of about 5,800 gallons per minute to the mine panels. At full operation two panels would be backfilled simultaneously from the roof of the panels. Drain pipes laid along the panel floor would collect the percolating water drained from the slurry. The water would be pumped back to the slurry plant for reuse. As a result of the natural down dip of the panels, each would be filled to the roof and then sealed with concrete.

Project Abandonment

The metal from the project facilities would be salvaged and hauled to Rifle, Colorado, for rail shipment. All other materials, such as the concrete, would be hauled to the landfill near Meeker, Colorado. To facilitate the establishment of vegetation, compacted areas would be broken up, or ripped, and disked, or harrowed, before placement of soil from the soil stockpiles. Except for the approximately 185 acres that would be farmed, disturbed areas would be treated by planting with native species, seeds would be drilled and mulched, while forbs and shrubs would be planted, or set. The areas would be fertilized and irrigated for two growing seasons using the existing irrigation facilities and portable piping and sprinklers. During the two-year period, fences around the mine and plant

Project Feature	Acres Required
<u>Mine:</u>	
Portal area	20
Soil stockpile, muck disposal area, and settling basin	20
Secondary access shaft	9
Reinjection wells	1
Roads, pipelines, and conveyors	21
<u>Plant:</u>	
Shale and process water storage basin	110
Plant site	170
Soil stockpiles	<u>29</u>
Total	380

LAND REQUIREMENTS FOR THE PROPOSED SUPERIOR OIL PROJECT

TABLE 1-8

Water Source	Quantity	Project Component	Time Frame	Use
White River	6,000 gallons/day	Construction	6 months	Potable water (hailed from Meeker)
White River	23,000 gallons/day	Construction	4.5 years	Potable water (treated on site)
White River	9,000 gallons/day	Operation	22.5 years	Fire loop testing
Piceance Creek	3.7 acre-feet/year	Construction	5 years	Irrigation (soil stockpiles)
Piceance Creek	52.6 acre-feet/year	Abandonment	1.25 years	Irrigation
Lower aquifer	3.3 million gallons/day	Operation	20 years	Process water

Note:

Specific time frames are shown in Figure 1-2.

WATER REQUIREMENTS FOR THE PROPOSED SUPERIOR OIL PROJECT

TABLE 1-9

Rio BLANCO Oil SHALE COMPANY

TRACT C-A

**Modification to the
Detailed Development Plan**

LURGI DEMONSTRATION PROJECT

**Submitted February 1981 to the
USGS Deputy Conservation Manager-Oil Shale
by Rio Blanco Oil Shale Company**

**A General Partnership of
Gulf Oil Corporation/Standard Oil Company (Indiana)
2851 South Parker Road, Aurora, Colorado 80014**

TABLE 1-1-2

LURGI DEMONSTRATION PROJECT SUMMARY

	<u>PHASE I</u>	<u>PHASE II</u>
<u>TIMING</u>		
Construction		
Process Plant	May 81 - Jan 83	
Mine (Overburden Stripping)	May 81 - Feb 83	Nov 83 - Feb 85
Operation		
Process Plant	Jan 83 - July 84	July 84 - Jan 86
Mine (Ore Production)	Feb 83 - Apr 83	Feb 85 - May 85
<u>MINING</u>		
Type	Open Pit	Open Pit
Overburden Quantity	5.2 MM/bcy	4.2 MM/bcy
Overburden Haulage	Truck	Truck
Ore Production	1.2 MM Tons	1.8 MM Tons
Ore Haulage	Truck	Truck
Transfer from MIS Stockpile	Up to 0.3 MM Tons	
MIS Ore Haulage	Truck	
<u>PROCESSING</u>		
Retorting	Lurgi 4400 TPD Unit	Lurgi 4400 TPD Unit
Processed Shale Quantity (Includes Moisturization)	1.2 MM Tons	1.8 MM Tons
Processed Shale Haulage	Conveyor Belts	Conveyor Belts
Stream Days	0.5 Factor	0.75 Factor
<u>PRODUCT SHALE OIL</u>		
Transportation Quantity	Truck 1,000 B/D Avg	Truck 1,500 B/D Avg
<u>AREA DISTURBED</u>	559 Acres	214 Acres
<u>NET GROUND WATER USED</u>	350 AFY	500 AFY
<u>POWER PURCHASED</u>	11 MW	11 MW

Figure 7-6-22 shows possible water flow paths and normal flow rate values for the construction phase.

B. Operation Phase - Water will be generated during the operation phase of the Lurgi Demonstration Project from water supply wells and from ground water flow into the surface mine. Flow into the surface mine will be removed from the mine and directed to a settling pond where it will be treated to reduce sediment loads. These two sources will be used to supply all Lurgi Demonstration Project demands during the operation phase. The water management plan for this Phase has been designed with enough flexibility that water required for any demand can be supplied by either source. These demands include operational and potable water for the Lurgi processing system and the processed shale disposal system, dust control water for the surface mine system and miscellaneous closed systems, and operational water for the surface mine system. When extremely dry conditions occur on-site for extended periods of time, water may be supplied from one or both sources for irrigation of reclamation vegetation at various site locations. Water supplied to the various systems will normally be lost by evaporation, seepage and consumptive use. The only normally occurring discharge will be treated sanitary effluent from the surface mine system and the MIS facility. However, to maintain flexibility in the operation, the option to discharge tertiary treated waste streams from the Lurgi processing facility will also be maintained.

Any surplus source water, usually from excess ground water flow into the mine, will be injected into the Upper Aquifer to contain the spread of the ground water depression cone in areas where significant hydrologic impacts will occur. It may be necessary to discharge some surplus mine water to Dry Fork under an NPDES permit.

Infrequently, precipitation events will occur over the site area, inputting additional water into the systems. Precipitation falling directly on the MIS and Lurgi processing facilities will be incorporated into the process streams. Runoff from precipitation falling directly on processed shale or raw shale ore will be collected and evaporated. All other runoff from disturbed areas will be collected in settling ponds for treatment to reduce

sediment loads and discharged to the natural drainage system. Runoff from undisturbed areas will be diverted around the operations to the natural stream.

Figure 7-6-23 shows possible water flow paths and normal flow rates for all systems during the Lurgi Demonstration Project operation phase.

C. Abandonment Phase - During the abandonment phase of the Lurgi Demonstration Project, all water needs will be supplied by the water supply well system. Water from wells will normally flow to the surface mine system and miscellaneous closed systems for dust control and to the surface mine system for housekeeping water. When extremely dry conditions occur on the site for extended periods of time, additional water may be drawn from the wells for irrigation of reclamation vegetation at various site locations. All water supplied to the systems, with the exception of treated sanitary effluent from the surface mine system and the MIS facility, will normally be lost to evaporation or consumptive use. The treated surface mine system sanitary effluent will normally be discharged to Dry Fork, and that from the MIS facility will be discharged to Corral Gulch.

Infrequently, precipitation events will occur over the site area. Until all disposed shale is reclaimed, runoff from precipitation falling directly on such shale will be collected and evaporated. Runoff from other disturbed site areas will be collected, treated to reduce sediment loads and discharged to the natural system. Such collection, treatment and discharge will continue at each disturbed area until final reclamation of that area is achieved.

Figure 7-6-24 shows possible flow paths and normal flow rates during the Lurgi Demonstration Project abandonment phase.

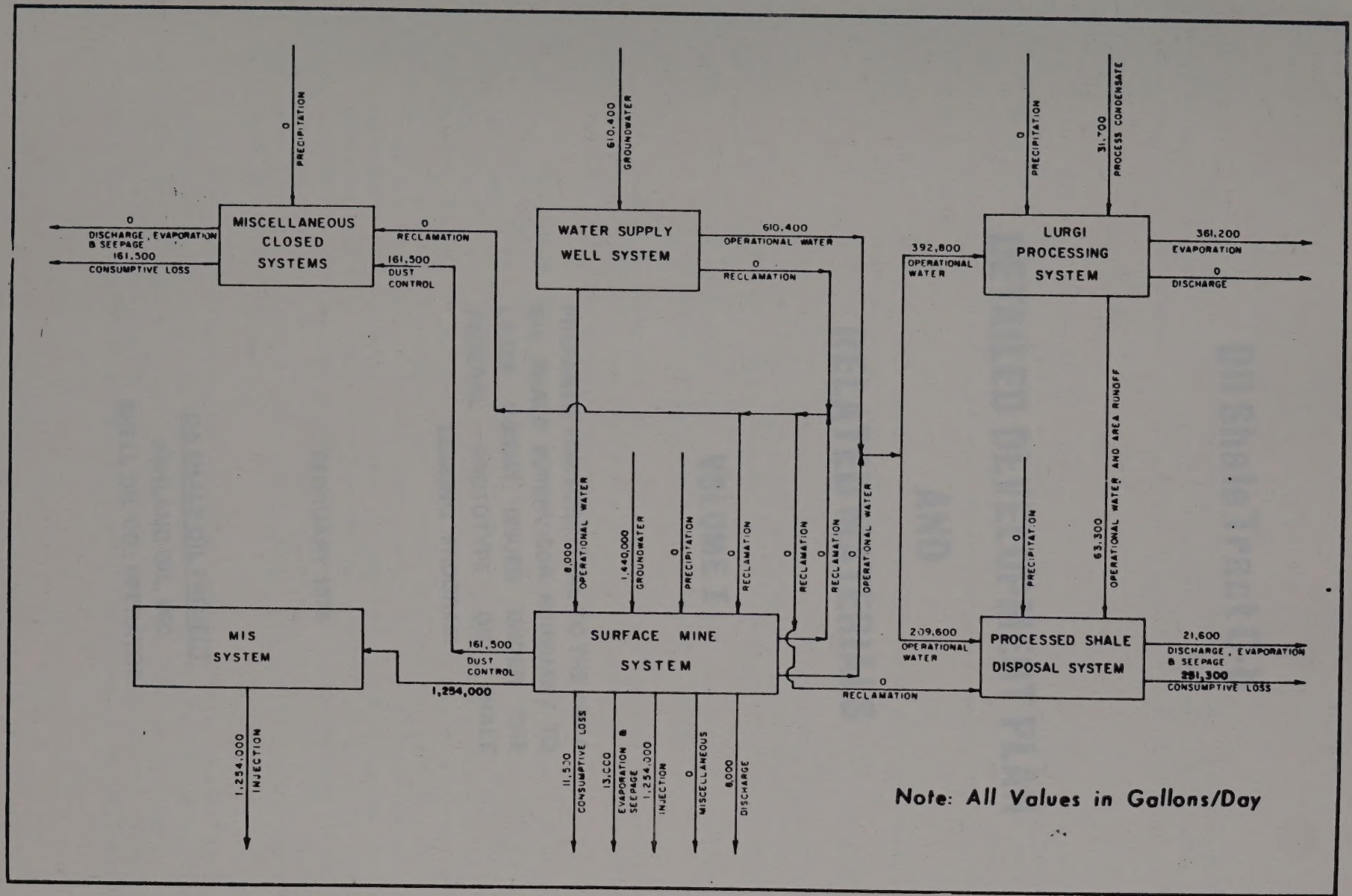


Figure 7-6-23
Summary Water Flow Diagram - Operation Phase

Oil Shale Tract C-b

DETAILED DEVELOPMENT PLAN AND RELATED MATERIALS

VOLUME I

**PREPARED FOR SUBMITTAL TO THE AREA
OIL SHALE SUPERVISOR PURSUANT TO
LEASE C-20341 ISSUED UNDER THE
FEDERAL PROTOTYPE OIL SHALE
LEASING PROGRAM**

FEBRUARY 1976

**C-b SHALE OIL PROJECT
ASHLAND OIL, INC.
SHELL OIL CO., OPERATOR**

F. Waste Disposal

See sections V. G., Overburden Management, V. H., Processed-shale Disposal and V. I., Disposal of Other Wastes, for further details on Lessee's environmental control plans regarding waste disposal.

G. Water Use

Water is utilized in a wide variety of operations within the mine and plant complex. The total consumptive use during normal operations will be approximately 5500 GPM (12.3 CFS) for a 50,000 barrel per day plant. The following tabulation and Figure IV-29 show plant water requirements by plant area, with approximate percentage distributions and form of use.

- mining (9%) - wetting down blasted shale and mine roads and suppression of drilling dust
- crushing, conveying and coarse-ore storage (3%) - suppression of dust with water sprays
- retorting and upgrading (55%) - cooling water, steam generation, hydrogen production, coke cutting and evaporation loss
- processed-shale disposal (28%) - dust control, moisturizing water and revegetation
- general plant and personnel use (5%) - utility water, fire protection, potable water and sanitary sewage

During construction, 800 to 1200 acre-feet of water per year will be required for concrete manufacture, dust control, compaction of grades and fill and other general and personnel uses.

All water supplied to the plant is eventually consumed or recycled in some way or released to the atmosphere by evaporation. There should be no water discharge beyond the Tract boundaries unless excessive mine water flows are encountered. A major consumptive use of water is the moisturization of processed shale, for which all waste water streams not otherwise recycled will be used. Water used for moisturizing processed shale for reclamation or for dust control on the processed-shale embankment will either evaporate, be permanently incorporated into the waste pile or will drain into the catchment basin for recycle. Other consumptive uses include steam generation in the reforming process to produce hydrogen for the hydrotreating units, use as drinking water, evaporation losses from the cooling tower, and use as irrigation water used in revegetation.

The plant cooling-water system is comprised of a complex network of piping over the entire processing area. About 36,000 GPM of cooling water will circulate within the plant and will eventually return to a multiple-cell cooling tower with an induced-draft air flow. Blowdown from the cooling-water system will go to the processed-shale moisturizer.

FINAL
ENVIRONMENTAL STATEMENT
FOR THE
PROTOTYPE OIL-SHALE LEASING PROGRAM

Volume I of VI
Regional Impacts
of
Oil Shale Development

Prepared in Compliance With
Section 102 (2) (c) of the National Environmental
Policy Act of 1969

Prepared by
UNITED STATES DEPARTMENT OF THE INTERIOR
1973

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Table III-5.-- Water Consumed for Various Rates of Shale Oil Production ^{1/} (Acre-feet/year).

Shale Oil Production (Barrels per day)

	50,000 Underground	100,000 Surface Mine	50,000 In Situ	400,000 Technology Mix ^{2/}	1,000,000 Technology Mix ^{2/}
PROCESS REQUIREMENTS					
Mining and Crushing	370- 510	730-1,020	---	2,600- 3,600	6,000- 8,000
Retorting	580- 730	1,170-1,460	---	4,100- 5,100	9,000-12,000
Shale Oil Upgrading	1,460-2,190	2,920-4,380	1,460-2,220	11,700-17,500	29,000-44,000
Processed Shale Disposal	2,900-4,400 ^{3/}	5,840-8,750 ^{3/}	---	20,400-30,900	47,000-70,000
Power Requirements	730-1,020	1,460-2,040	730-1,820	5,800- 9,200	15,000-23,000
Revegetation	0- 700	0- 700	0- 700	0- 4,900	0-12,000
Sanitary Use	20- 50	30- 70	20- 40	200- 300	1,000- 1,000
Subtotal	6,060-9,600	12,150-18,420	2,210-4,780	44,800-71,500	107,000-170,000
ASSOCIATED URBAN					
Domestic Use	670- 910	1,140-1,530	720-840	5,400-6,900	13,000-17,000
Domestic Power	70- 90	110- 150	70- 80	500- 600	1,000- 2,000
Subtotal	740-1,000	1,250-1,680	790-920	5,900-7,500	14,000-19,000
GRAND TOTAL	6,800-10,600	13,400-20,100	3,000-5,700	50,700-79,000	121,000-189,000
AVERAGE VALUE	8,700	16,800	4,400	65,000	155,000

^{1/} Assumes the same technologies as those used to develop Table III-2.

^{2/} Assumes development schedule as those shown in Table III-2.

^{3/} Water used is 20% by weight of the disposed spent shale.

Sources: Water requirements for mining, crushing, retorting, and shale-oil upgrading are based on process engineering studies by the U.S. Bureau of Mines (8). Water power requirements are based on Jameson and Adkins (9). The water needs for shale disposal are based on stability research by Denver Research Institute (10) on experimental work by Colorado State University (4) and by the Colony Development Operation (11). Water requirements for revegetation of processed or spent shale will range from zero as a given area is built up, to about 1 foot per year for each acre to be revegetated (12). Urban population associated with a given plant size was made by the U.S. Bureau of Mines (8), and the water demands per capita have been obtained from the work of Ryan and Wells (13).

water requirements could make additional
quantitative analysis. The extent of the increase
cannot be predicted accurately, and the state-

ties could be impacted by local, institutional,
and economic factors.

Analysis of Water Requirements for Oil Shale Facilities*

Introduction

Water will be used for oil shale mining and
retorting, for shale oil upgrading, for recon-
struction and other shale disposal, and for
processing the recovered petroleum and other
valued substances that will accompany the
treatment of a shale. Water for the shale
water will be needed for the shale oil
operations can be carried out in the shale
regions. In the early years of the industry,
some shale oil will probably be refined in the
oil shale regions and mostly in Denver and
Salt Lake City. Water is also scarce in these
areas. However, the retorting now presently
consuming water for processing conventional
petroleum. Shale oil will merely displace the
conventional hydrocarbons, thus its refining will
not add significantly to water requirements.
In the long run, the output of a major industry

*This analysis assumes that the quantity of water required
for a given process with a stream of water is
proportional to the quantity of the product, water used
for the process, and the water consumption. The
processes described with present technology give future
discharge and consumption figures.

would be refined in the Midwest where water
is abundant.

Estimates of water consumption vary widely.
In the following section the most recent

An Assessment of Oil Shale Technologies

Process and Facility Models Analyzed

Facilities that use six retorting processes
are described in table 71. The processes were
selected for analysis because of their advance-
ment development and because data have been
published on their water requirements. The
processes fall into three generic classes:
directly heated aboveground retorting (AGR),
indirectly heated AGR, and modified in situ
(MIS) retorting. The facilities modeled are

1. TUSCO II indirectly heated AGR
2. Petrobr directly heated AGR

Table 71 - Process Models for Oil Shale Facilities

OTA Reports are the principal documentation of formal assessment projects. These projects are approved in advance by the Technology Assessment Board. At the conclusion of a project, the Board has the opportunity to review the report but its release does not necessarily imply endorsement of the results by the Board or its individual members.



CONGRESS OF THE UNITED STATES
Office of Technology Assessment
Washington, D. C. 20510

weather modification could make additional quantities available. The extent of the increase cannot be predicted accurately, and the strate-

gies could be impeded by legal, institutional, and economic factors.

Analysis of Water Requirements for Oil Shale Facilities*

Introduction

Water will be used for oil shale mining and retorting, for shale oil upgrading, for revegetation and spent shale disposal, and for supplying the increased population and other related activities that will accompany the establishment of a shale oil industry. More water will be needed for final refining but this operation can be carried out at other locations. In the early years of the industry, some shale oil will probably be refined in the oil shale region and nearby in Denver and Salt Lake City. Water is also scarce in these areas. However, the refineries are presently consuming water for processing conventional petroleum. Shale oil will merely displace the conventional feedstocks, thus its refining will not add significantly to water requirements. In the long run, the output of a major industry

would be refined in the Midwest where water is abundant.

Estimates of water consumption vary widely. In the following section the most recent estimates for alternative technologies on specific sites are analyzed, and then compared with estimates of regional water availability in order to identify the level of shale oil production at which water resources might limit further development.

Process and Facility Models Analyzed

Facilities that use six retorting processes are described in table 71. The processes were selected for analysis because of their advanced development and because data have been published on their water requirements. The processes fall into three generic classes: directly heated aboveground retorting (AGR), indirectly heated AGR, and modified in situ (MIS) retorting. The facilities modeled are:

1. TOSCO II indirectly heated AGR,
2. Paraho directly heated AGR,

*This analysis assumes that the quantity of water removed for a given purpose from a stream or aquifer (the water requirement) is numerically equal to the quantity made unavailable for subsequent uses (the water consumption). This assumption is consistent with present developer plans for zero-discharge water management systems.

Table 71.—Process Models for Oil Shale Facilities

Technology	Study	Refer- ence ^a	Colorado location	Shale grade gal/ton	Shale oil capacity	Other major product	Byproducts, ton/d		
							Coke	Sulfur	Am- monia
TOSCO II ^b	Colony	3	Davis Gulch	35	47,000 bbl/d syncrude	LPG: 4,330 bbl/d	800	173	135
TOSCO II ^b	WPA/DRI	1	Davis Gulch	35	47,000 bbl/d syncrude	LPG: 4,330 bbl/d	800	173	134
Paraho direct	McKee-Kunchal	4	Anvil Points	30	87,000 bbl/d syncrude	Low-Btu gas: 32 billion Btu/d	650	136	290
Paraho direct	WPA/DRI	1	Anvil Points	29	99,170 bbl/d crude	Electricity: 155 mW ^c	0	132	146
Paraho indirect	McKee-Kunchal	4	Anvil Points	30	76,000 bbl/d syncrude	Low-Btu gas: 6 billion Btu/d	650	136	290
Union "B" ^b	Eyring/Sutron	10	Parachute Creek	34	100,000 bbl/d syncrude	(d)		d	
Oxy MIS	Oxy	5,9	Tract C-b	24	57,000 bbl/d crude	Electricity: 350 mW ^e	0	92	0
Oxy MIS	WPA/DRI	1	Tracts C-a or C-b	25	57,000 bbl/d crude	Electricity: 97mW ^c	0	144	281
Oxy MIS + Lurgi	WPA/DRI	1	Tracts C-a or C-b	25	81,000 bbl/d crude	Electricity: 140 mW	0	172	281

^aSee reference list at end of chapter. ^bElectricity purchased. ^cOpen-cycle gas turbines. ^dData not provided. ^eCombined-cycle system.

SOURCE: R. F. Probst, et al., *Water Requirements, Pollution Effects, and Costs of Water Supply and Treatment for the Oil Shale Industry*, report prepared for OTA by Water Purification Associates, October 1979, p. 4.

3. Paraho indirectly heated AGR,
4. Union Oil "B" indirectly heated AGR,
5. Occidental Oil Shale's directly heated MIS retorts, and
6. a combination of directly heated MIS retorts and Lurgi-Ruhrgas indirectly heated AGR.

The water requirements of these facilities were scaled to a common basis of 50,000 bbl/d of synthetic crude oil. Thus, units for upgrading crude shale oil to a high-quality synthetic crude are included. Each facility generates sufficient electric power for its own needs, and all solid waste dumps are revegetated. Wastewater is recycled wherever practical, and only excess mine drainage water is discharged or reinjected. Disposing of solid wastes by slurry backfill, either to the mine or to the burned-out in situ retorts, is not included. The effects of byproduct coke, ammonia, sulfur, or gas are not evaluated. True in situ processes are not analyzed because no data are available.

With the exception of the Union "B" plant, each estimate discussed in this section is derived from a published conceptual design,¹⁻⁹ either the developer's or one that has been modified to put plant material and energy balances on a consistent basis. Although little in-

formation has been published, the Union process is considered here because plans for a plant have been announced.¹⁰ However, the data cannot be treated with the same confidence as for other processes.

A number of other studies¹¹⁻¹⁵ have been completed but are not discussed in this section. Although they were based on data supplied by the developers, their conclusions did not agree because different retorting procedures, products, production rates, power supply modes, shale grades, and disposal procedures were assumed.

Water Requirements

The water requirements of the six oil shale facilities, after scaling, are summarized in table 72. As can be seen, even facilities that use similar processes (e.g., indirect AGR) require different amounts of water. However, when the requirement for each subprocess is represented as a percent of the total, there is a correlation among different plants that use similar kinds of technology, as shown in table 73. It is noteworthy that:

- Mining and dust control require considerably more water in AGR than in either MIS or MIS/AGR. This is because about

Table 72.—Water Requirements and Mine Drainage Production for 50,000-bbl/d Oil Shale Facilities (acre-ft/yr)

Retorting technology	Paraho direct		TOSCO II		Paraho indirect	Union "B"	Oxy MIS		MIS/AGR	
Study	McKee-Kunchal	WPA/DRI	Colony	WPA/DRI	McKee-Kunchal	Eyring-Sutron	Oxy 1977	Oxy 1979	WPA/DRI	WPA/DRI
Reference ^a	4	1	3	1	4	9	5	9	1	1
Unit operation										
Mining and handling . . .	816	941	1,045	1,045	934	—	483	483	338	326
Power generation	665	(b)	1,233	1,233	761	1,233	(b)	(b)	(b)	(b)
Retorting and upgrading	2,616	2,375	5,038	3,821	3,487	1,470	9,234	2,502	3,601	3,051
Shale disposal and revegetation	1,644	1,385	3,895	3,956	4,020	3,090	2,818	1,103	1,103	1,461
Municipal use	645	645	594	594	731	731	775	775	775	818
Net water requirements										
In acre-ft/yr	6,386	5,346	11,805	10,694	9,933	6,524	13,310	4,863	5,817	5,656
In bbl water/bbl oil	2.71	2.27	5.02	4.53	4.22	2.77	5.66	2.06	2.47	2.40
Mine drainage water										
In acre-ft/yr	(b)	(b)	(b)	(b)	(b)	(b)	6,440-16,100	4,032-6,452	12,326	8,454
In bbl water/bbl oil	(b)	(b)	(b)	(b)	(b)	(b)	2.74-6.86	1.56-2.50	5.25	3.60

^aSee reference list at end of chapter.

^bNot applicable for project or site analyzed.

SOURCE: R. F. Probst, et al., *Water Requirements, Pollution Effects, and Costs of Water Supply and Treatment for the Oil Shale Industry*, report prepared for OTA by Water Purification Associates, October 1979, p. 8.

Table 73.—A Comparison of the Water Requirements of the Various Subprocesses

Subprocess	Generic technology (in percent)		
	Indirect and direct AGR	MIS/AGR	MIS
Mining and handling	9-18	6	4-10
Power generation	8-12	(a)	(a)
Retorting and upgrading . .	35-44	54	51-69
Disposal and revegetation .	26-40	26	19-26
Municipal use	5-12	14	6-16

^aNot applicable for project or site

SOURCE R. F. Probst, et al., *Water Requirements, Pollution Effects, and Costs of Water Supply and Treatment for the Oil Shale Industry*, report prepared for OTA by Water Purification Associates, October 1979, p. 9.

four times as much shale is mined and handled in aboveground processing. The larger amount of material also results in high water requirements for disposal and revegetation.

- No water is needed for power generation in MIS and MIS/AGR because power will most likely be generated by burning low-Btu gases in open-cycle gas turbines that do not need to be cooled. Even if combined-cycle systems were used, very little cooling water would be needed. Cooling water is needed for AGR because solid-fuel steam-cycle systems will probably be used.
- Municipal water needs are proportional to the number of mine and plant employees. For the same output, more workers are required for MIS (about 1,800) than for AGR (about 1,400 to 1,700). It is assumed that the MIS/AGR process would require slightly more workers (about 1,900) than either technology by itself.

Retorting and upgrading require the most water. All the technologies need comparable amounts of water for upgrading, therefore, the differences among alternate technologies reflect differences in retorting efficiencies. The large differences between similar aboveground technologies result from specific operating characteristics, especially the methods for heating the retort and for disposing and reclaiming the spent shale. More water is required for indirect than for direct AGR because indirect heating has a significantly lower overall thermal efficiency.

Spent shale disposal and reclamation require large amounts of water in the TOSCO II and Paraho indirect designs (about 4,000 acre-ft/yr), while the estimate for the Paraho direct process is about 60 percent lower. Largely because of this difference, the overall requirement for Paraho direct is only about 5,900 acre-ft/yr, while the TOSCO II and Paraho indirect designs need about 10,500 acre-ft/yr or almost twice as much.

The requirements for MIS retorting and upgrading are similar to those for indirect AGR. However, because little water is needed for mining and waste disposal, overall water requirements for MIS are similar to those for direct AGR; that is, about 5,800 acre-ft/yr. For similar reasons, the requirements for MIS/AGR are similar to those for MIS alone.

It has been assumed that none of the AGR plants will produce mine drainage water. The MIS and MIS/AGR facilities, however, are assumed to produce such water in substantial quantity. This difference is not related to the technologies but rather reflects the siting assumptions made for the various plants. The MIS and MIS/AGR facilities are on tracts C-a and C-b in the ground water areas of the central Piceance basin, while the AGR operations are in drier areas along the southern fringe of the Piceance basin or the eastern portion of the Uinta basin. Mining in ground water areas produces mine drainage water that must either be used, discharged, or reinjected. The amount produced varies with location. Estimates for tract C-b range from 4,032 to 16,100 acre-ft/yr¹⁶ and for tract C-a to at least 18,100 acre-ft/yr.¹⁷ This water should be regarded as an alternate water resource and not as part of the process. Similar operations in other locations may not produce comparable amounts of water.

An Evaluation of Assumptions in the Estimates

Detailed breakdowns of the water required and produced by each principal operation in each model facility are shown in table 74. (Table 72 was derived from these data.)

Table 74.—Breakdown of Water Requirements and Water Production for 50,000-bbl/d Oil Shale Facilities (acre-ft/yr)

	Paraho direct		TOSCO II		Paraho indirect	Union "B"		Oxy MIS			MIS/AGR
	McKee-Kunchal	WPA/DRI	Colony	WPA/DRI	McKee-Kunchal	Eyring-Sutron	Oxy 1977	Oxy 1979	WPA/DRI	WPA/DRI	
Water required											
Mining and ore handling	816	941	1,045	1,045	934	(a)	483	483	338	326	
Power generation	832 ^b	(c)	1,850 ^b	1,850 ^d	952 ^d	1,850 ^d	(c)	(c)	(c)	(c)	
Retorting and upgrading											
Cooling tower makeup	3,849	3,854 ^e	3,861	3,939	4,406	—	6,875 ^e	806	4,494 ^e	3,626 ^e	
Retorting	—	0	1,884	668	—	—	2,731	3,753	2,731	1,873	
Upgrading	—	939 ^d	939	939	—	—	939 ^d	939 ^d	939 ^d	939	
Other boiler makeup	1,224	490 ^e	557	557	1,401	1,710 ^b	985 ^e	525	551 ^e	529 ^e	
Steam and treatment loss	—	50	572	572	—	—	39	587	109	75	
Service and fire water	—	69	60	60	—	—	(a)	2,111	67	60	
Potable and sanitary	—	39	34	34	—	—	113	161	31	28	
Disposal and reclamation											
Shale moisturizing	(c)	(c)	2,859	2,920	(c)	—	(c)	(c)	(c)	(c)	
Disposal and compaction	1,664	972	428	428	—	2,870	1,208	346	346	1,239 ^e	
Revegetation	—	413	608	608	4,020	220	1,610	757	757	222 ^d	
Municipal demand	1,614 ^b	1,614 ^b	1,485 ^b	1,485 ^b	1,829 ^b	1,829 ^b	1,937 ^b	1,937 ^b	1,937 ^b	2,045 ^d	
Total required	9,979	9,378	16,182	15,105	13,542	8,479	16,920	12,405	12,300	10,962	
Water produced											
Power generation	167 ^d	(c)	617 ^d	617 ^d	191 ^d	617 ^d	(c)	(c)	(c)	(c)	
Retorting and upgrading											
Cooling tower blowdown	768	1,653 ^e	1,240	1,319	880	(a)	625 ^e	(a)	1,038 ^e	907 ^e	
Retort condensate	127	(a)	(a)	(a)	388	240	1,243	2,419	1,243	852	
Gas condensate	752	542	728	728	125	—	(a)	3,072	2,157	1,480	
Upgrading condensates	540	103 ^d	103	103	618	(a)	103 ^d	103	103	103	
Boiler and treatment											
waste	270	487 ^e	557	557	309	(a)	486 ^e	384	530 ^e	513 ^e	
Service water effluent	(a)	30	27	27	(a)	(a)	(a)	241	26	27	
Potable and sanitary effluent	(a)	26	26	26	(a)	(a)	(a)	161	23	20	
Surface runoff	(a)	222	188	188	(a)	(a)	(a)	(a)	201	177	
Municipal effluent	969 ^d	969 ^d	891	891 ^d	1,098 ^d	1,098 ^d	1,162 ^d	1,162 ^d	1,162 ^d	1,227 ^d	
Total produced	3,593	4,032	4,377	4,456	3,609	1,955	3,619	7,542	6,483	5,306	
Net consumption											
In acre-ft/yr	6,386	5,346	11,805	10,649	9,933	6,524	13,301	4,863	5,817	5,656	
In bbl water/bbl oil	2.71	2.27	5.02	4.53	4.22	2.77	5.65	2.06	2.47	2.40	
Mine drainage											
In acre-ft/yr	(c)	(c)	(c)	(c)	(c)	(c)	6,440-16,100	4,032-6,452	12,326	8,454 ^e	
In bbl water/bbl oil	(c)	(c)	(c)	(c)	(c)	(c)	2.74-6.86	1.56-2.50	5.25	3.60 ^e	

^aNot provided ^bIncludes mining and retorting ^cNot applicable. ^dEstimated by OTA ^eModified for OTA.

SOURCE: R. F. Probst, et al. *Water Requirements, Pollution Effects, and Costs of Water Supply and Treatment for the Oil Shale Industry*, report prepared for OTA by Water Purification Associates, October 1979, p. 14.

Paraho Direct

The two estimates for Paraho direct are reasonably consistent. However, the McKee/Kunchal water management plan is not sufficiently detailed for a thorough evaluation to be made of the differences that appear. The two designs differ principally in the mode of power generation. The McKee/Kunchal de-

sign assumed that a water-cooled steam cycle would be used; the Water Purification Associates/Denver Research Institute (WPA/DRI) design assumed that low-Btu gas would be burned in open-cycle gas turbines that require no cooling water.

The retorts are also operated differently. A higher retorting temperature is assumed in

the WPA/DRI design, and the water produced during retorting is vaporized and exhausted. In the McKee/Kunchal design, lower temperatures cause partial condensation of the retort water. Also, upgrading was not considered by WPA/DRI, and it was necessary to adapt estimates from the TOSCO II plant design.

The chief uncertainty is the claim of minimal water needs for spent shale disposal. The WPA/DRI design, which was based on this claim, uses a conservative estimate of 5 percent by weight of water for compaction and a separate estimate for revegetation. The McKee/Kunchal estimate is not directly comparable because it combines compaction and revegetation. However, the total values are reasonably consistent.

Paraho's claim that proper compaction can be obtained with small water additions is based on evidence from disposing about 150 ton/d of spent shale. It is uncertain that sufficient moisture could be extracted from the atmosphere to dispose of 72,000 ton/d, the output of a 50,000-bbl/d plant.

TOSCO II

Although the Colony water management plan is very detailed, neither Colony nor WPA/DRI assumed onsite power generation. OTA's analysis assumed that about 85 MW of power would be generated by a steam-cycle system.

A principal difference between the designs is that WPA/DRI substituted a bag filter and electrostatic precipitator for Colony's venturi wet scrubbers, thereby reducing water consumption. Both designs assumed that the spent shale is moisturized to 14 percent by weight of water to allow proper compaction. For revegetation, both designs assumed an average value of 608 acre-ft/yr over the 20-year life of the plant. During the first 10 years, little revegetation would be done and water would be used only for compaction and dust control. In the second 10 years, revegetation programs would be expanded and water needs would increase.

Paraho Indirect

It is not possible to fully evaluate the Paraho indirect estimates because the McKee/Kunchal report lacks a detailed water management scheme. Compared with TOSCO II, retorting and upgrading requirements appear low. Also, the requirement for revegetation is much higher than for all other retorts. The reason given is the high carbon content of the spent shale, but this conclusion is not supported by Union's experience with similar retorted shale. The high estimates for revegetation may have been made to offset low estimates for compaction.¹⁸

Union Oil "B"

Because only crude data are available, judgment should be reserved on the low estimates for mining, retorting, and upgrading. The Environmental Protection Agency (EPA) recently published a considerably higher estimate for mining and processing that would lead to a total consumption more in line with estimates for other processes.¹⁹ Unfortunately, the higher estimate cannot be verified because no background information was supplied. An older EPA document²⁰ provides a value for mining and processing consistent with the Eyring/Sutron estimate. The relatively large requirement for spent shale disposal is a consequence of Union's method for cooling the hot retorted shale by immersing it in water.

Occidental (Oxy) Modified In Situ

The older Oxy estimate differs significantly from the WPA/DRI design in both water requirements and water production. Oxy's requirements are higher for cooling water, for raw shale disposal, and for revegetation. It appears that these uses were deemed appropriate for disposing of excess mine drainage water. Much less water is wasted in the WPA/DRI design and in the newer Oxy plan. Also, the production of retort condensate was not estimated in the older Oxy plan. The WPA/DRI estimate (2,157 acre-ft/yr) was based on Oxy's estimates of the steam flows

to the retorts. (Much more condensate would be produced if ground water entered the retorts during their operation.) WPA/DRI also assumed that the retort gases are not compressed prior to gas cleaning. This reduces the cooling water requirement, although it increases the cost of the gas cleaning equipment. The net difference (considering condensate production and cooling water reduction) is about 6,700 acre-ft/yr, which accounts for most of the discrepancy between Oxy's older plan and the WPA/DRI study. In general, the WPA/DRI results agree quite well with Oxy's current water management plan.

Modified In Situ/Aboveground Retorting

The only published water management plan for a combined facility is that of the Rio Blanco project on tract C-a. Details are not sufficient for a thorough evaluation and the plan is now obsolete because Rio Blanco has since revised its approach. The WPA/DRI model, which combines MIS with Lurgi-Ruhr-gas retorts, is similar to the current plans for the tract.

The principal difference between OTA's process model and those of Rio Blanco or WPA/DRI is that OTA has assumed surface disposal of the spent shale, whereas the others assumed that the waste is returned as a slurry to the burned-out in situ retorts. In OTA's analysis, it is assumed that the vapor losses during moisturizing are the same as in underground slurry disposal. The estimates for both revegetation and upgrading were linearly scaled from the TOSCO II requirements. The accuracy limitations noted in the MIS discussion also apply here.

Municipal Use

It is assumed that the total population growth will be 5.5 times greater than the number of employees.²¹ Because this large multiplier is applied to uncertain employment figures, the estimates of municipal water needs are approximate. An aggregate requirement of 175 gal/person/d has been assumed, with consumption at 40 percent of

this figure. The net requirement—70 gal/person/d—is conservatively high. The average requirement for all the facilities considered is about 700 acre-ft/yr.

Mine Drainage Water

Probably the largest uncertainty of all, because it is highly site dependent, is the amount of mine drainage water produced. As noted above, estimates for the Federal lease tracts range from 6,400 to over 18,000 acre-ft/yr. This water should satisfy the processing needs of the technologies proposed for tracts C-a and C-b. However, these needs could probably not be satisfied by ground water on sites along the edge of Piceance basin.

Range of Water Requirements

The most likely ranges of the quantities of water that will be consumed by the three generic technologies and by the combined plant are indicated in table 75. Also shown are the likely ranges of mine drainage water production on tracts C-a and C-b. Overall, the requirements range from 4,900 to 12,300 acre-ft/yr—the equivalent of from 2.1 to 5.2 bbl of water consumed for each barrel of oil produced. Given this range, a 1-million-bbl/d industry could require from approximately 100,000 to 250,000 acre-ft/yr. Actual water requirements would be determined by the mix of technologies used. In table 76, these requirements are estimated for an industry that would result if present projects, both active and proposed, were completed. Some features of this industry are:

- Indirect AGR, the method with the highest unit water requirement, constitutes 51 percent of the total production.
- Direct AGR and MIS, which require less water, constitute only 33 percent of production. The balance is provided by MIS/AGR, which has an intermediate requirement.
- About 43 percent of the production will result from mining in ground water areas in the central and northern Pice-

Table 75.—Likely Ranges of Water Requirements and Mine Drainage Production for Oil Shale Facilities Producing 50,000 bbl/d of Shale Oil Syncrude

Technology	Average shale grade, gal/ton	Water requirements ^a	
		Acre-ft/yr	Barrels per barrel of oil
Directly heated AGR	29-32	4,900-7,800	2.1-3.3
Indirectly heated AGR	32-35	9,400-12,300	4.0-5.2
Directly heated MIS	23-27	4,900-5,900	2.1-2.5
MIS/AGR	23-25	5,700-6,700	2.4-2.9
Location		Water production	
Mine drainage water.	C-a/C-b	4,000-16,100	1.6-6.9

^aNet water requirements. Low end assumes higher shale grade, open-cycle power systems, high retort efficiency, and lower waste disposal and reclamation needs. High end assumes lower shale grade, steam-cycle or combined-cycle systems, low retorting efficiency, and higher disposal and reclamation needs.

SOURCE: R. F. Probst, et al., *Water Requirements, Pollution Effects, and Costs of Water Supply and Treatment for the Oil Shale Industry*, report prepared for OTA by Water Purification Associates, October 1979, p. 22.

Table 76.—Water Requirements for Active and Proposed Oil Shale Projects

Project	Location	Deposit	Technology	Design capacity		Water requirements, acre-ft/yr		
				Barrels per day	Percent of total	For 50,000 bbl/d	For design capacity	Weighted contribution
Rio Blanco	Central Piceance basin	Wet	MIS/indirect AGR	76,000	16	6,200	9,424	992
Cathedral Bluffs	Central Piceance basin	Wet	MIS	57,000	12	5,400	6,156	648
Long Ridge	Southern Piceance basin	Dry	Indirect AGR	75,000	16	10,850	16,275	1,736
Colony	Southern Piceance basin	Dry	Indirect AGR	46,000	10	10,850	9,982	1,085
Sand Wash	Uinta basin	Dry	Indirect AGR	50,000	10	10,850	10,850	1,085
EXXON	Central Piceance basin	Wet	Indirect AGR	60,000	13	10,850	13,020	1,411
White River	Uinta basin	Dry	Direct AGR	100,000	21	6,350	12,700	1,334
Superior	Northern Piceance basin	Wet	Indirect AGR	11,500	2	10,850	2,496	217
Total				475,500	100		80,903	8,508

SOURCE: Office of Technology Assessment.

ance basin. These plants could obtain their process water from the aquifers in the mining zone. Surface water would not be needed.

The total production from this combination [475,000 bbl/d] would require 80,903 acre-ft/yr. On this basis, a 50,000-bbl/d plant would need about 8,500 acre-ft/yr; a 1-million-bbl/d industry about 170,000 acre-ft/yr.

The following sections will use these estimates in conjunction with estimates of surplus surface water availability and other critical factors to identify the level of shale oil production at which water scarcity might restrict development. The issues section of this chapter discusses the industries that might result if a different mix of technologies were used or if ground water were developed.

Water Resources: A Physical Description

Surface water is obtained from rivers and streams; ground water from underground aquifers. In some instances, these sources are physically connected and should not be evaluated independently. For example, if the ground water supplies in most Western States were fully utilized, surface flows would decrease.

Surface Water

The Colorado River system, which includes the Colorado River and its tributaries, supplies surface water to the oil shale region. The Colorado River flows 1,440 miles from source to mouth. Its drainage area of 244,000 mi² includes parts of seven States and Mex-



ENVIRONMENTAL CONTROL COSTS FOR OIL SHALE PROCESSES

October 1979

U.S. Department of Energy
Assistant Secretary for Environment
Office of Technology Impacts
Washington, D.C. 20545

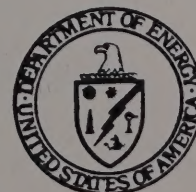


Table 6-4
OVERALL WATER BALANCE FOR PARAHO PROCESS PRODUCING 99,170 BPSD CRUDE SHALE OIL
WATER MANAGEMENT SCHEME IS SHOWN IN FIGURE 6-1

<u>IN</u>	<u>10³ lb/hr</u>	<u>gpm</u>
Source ^(a)	1,638	3,276
Net water produced by combustion ^(b)	187	374
Moisture in with shale	250	500
Moisture in combustion air	23	46
Runoff ^(c)	120	240
Mine water		~0
Total	<u>2,218</u>	<u>4,436</u>
 <u>OUT</u>		
Water in product oil	20	40
Spent shale and sludge moistening (5%)	525	1,050
Spent shale disposal, dust control, revegetation ^(d)	223	446
Cooling water evaporation and drift ^(e)	740	1,479
Dust control: At mine	317	633
: At plant (crushing and fugitive dust)	192	384
Potable, service; water consumed (assuming 2,600 employees ^(f))	26	54
Losses, condensate treatment and steam cycle ^(g)	28	56
Losses, product gas ^(h)	147	294
Total	<u>2,218</u>	<u>4,436</u>

(a) By difference.

(b) See note (g), Table 6-3.

(c) Value from Reference 7. Corresponds to ~15 inches rain/yr falling on 300 acres.

(d) Value from Reference 7. Total moisture on spent shale amounts to 71 lb H₂O/10³/lb spent shale as given in Reference 10.

(e) See Table 6-7.

(f) Based on data given in Reference 10.

(g) See Figure 6-1.

(h) See Figure 6-2 and Table 6-9.

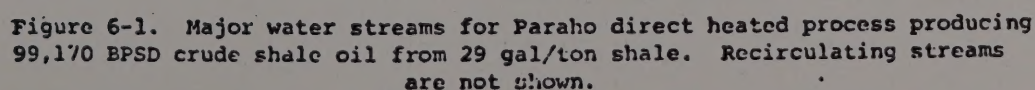


Table 6-21
OVERALL WATER BALANCE FOR TOSCO II PROCESS
PRODUCING 47,000 BPSD UPGRADED SHALE OIL

IN	Developer's Design ^(a)		Modified Design ^(b)	
	10 ³ lb/hr	gpm	10 ³ lb/hr	gpm
Source ^(c)	2,912	5,825	2,576	5,151
Moisture in with shale ^(d)	146	292	146	292
Net water produced by combustion ^(e)	-	-	-	-
Runoff ^(f)	55	110	55	110
Mine water	-	-	-	-
TOTAL IN	3,113	6,227	2,777	5,553
OUT				
Moistened spent shale ^(d)	632	1,264	632	1,264
Moisture out with coke ^(d)	5	10	5	10
Spent shale ^(g) Disposal dust control	125	250	125	250
Revegetation	178	355	178	355
Dust control ^(g) At mine	175	350	175	350
At plant	130	260	130	260
Cooling water, evaporation and drift ^(h)	765	1,530	765	1,530
Potable, service; water consumed (1,300 employees) ^(g)	12	24	12	24
Losses, condensate treatment ⁽ⁱ⁾	26	52	26	52
Losses, consumption, steam cycle ^(j)	142	286	143	286
Losses, process stacks ^(k)	923	1,846	586	1,172
TOTAL OUT	3,113	6,227	2,777	5,553

- (a) Retort water shown in Figure 6-5; overall water management in Figure 6-7.
(b) Retort water shown in Figure 6-6; overall water management in Figure 6-8.
(c) By balance on Figures 6-7 and 6-8.
(d) See Table 6-16.
(e) Note (w), Table 6-16 shows that net water formed by combustion is zero.
(f) Based on 15" rain/yr falling on 175 acres, 80% collection.
(g) Values based on data in Reference 10.
(h) See Table 6-24.
(i) See Figures 6-7, 6-9 and 6-10.
(j) Table 6-25 shows unspecified steam losses as 282 gpm. Values used here (286 gpm) to close balance.
(k) See Tables 6-16 and 6-17; sum of scrubber stack gases, water evaporated on shale, and water released with the CO₂ purge in the hydrogen production section.

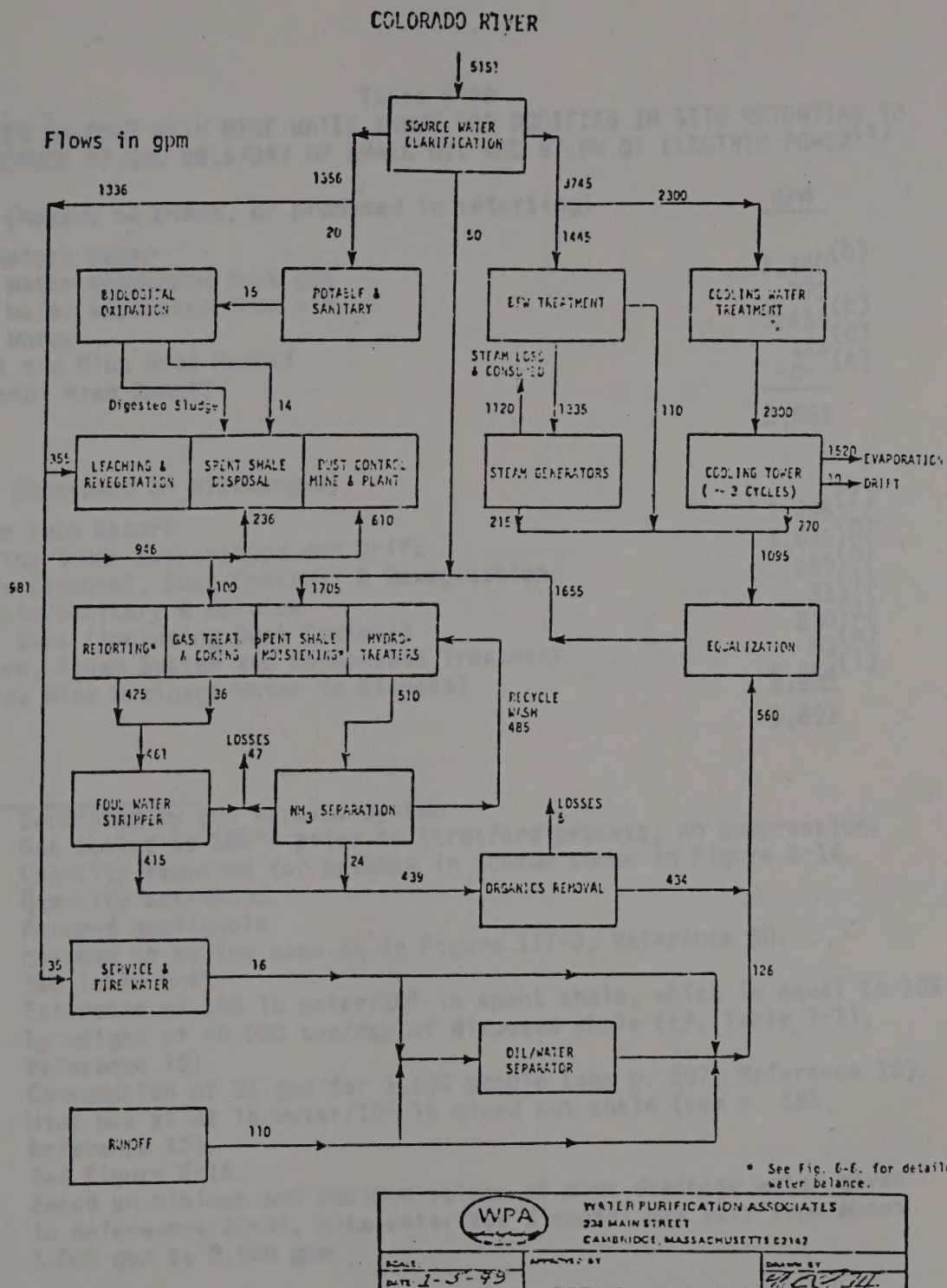


Figure 6-8. Major water streams for modified TOSCO II process in which venturi scrubbers have been replaced by bag filters. Other conditions as for Figure 6-7.

Table 6-39
WATER BALANCE WITH MINE WATER INPUT FOR MODIFIED IN SITU RETORTING TO
PRODUCE 57,000 BBLS/DAY OF SHALE OIL AND 97 MW OF ELECTRIC POWER^(a)

<u>IN</u> (Makeup to plant, or produced in retorting)	<u>GPM</u>
MIS Retort Water	
Water condensed from gas	1,340 ^(b)
Water separated from oil	772 ^(c)
Mine Water	7,656 ^(d)
Plant and Mine Area Runoff	125 ^(e)
Disposal Area Runoff	-0- ^(e)
	<u>9,893</u>
 <u>OUT</u> (Consumed or discharged)	
Steam into Retort	1,696 ^(f)
Cooling Tower Evaporation and Drift	1,636 ^(g)
Shale Disposal, Dust Control, & Revegetation	685 ^(h)
Potable/Sanitary & Service	31 ⁽ⁱ⁾
Mine Uses (including Dust Control)	210 ^(j)
Losses, Steam System and Condensate Treatment	83 ^(k)
Excess Mine Drainage Water to Disposal	5,554 ^(l)
	<u>9,893</u>

- (a) Generated by gas turbine system.
 (b) Gas cooled to 100°F prior to Stretford process; no compression.
 (c) Quantity required for balance in scheme shown in Figure 6-14.
 (d) Quantity estimated.
 (e) Assumed negligible.
 (f) Assumed to be the same as in Figure III-J, Reference 30.
 (g) See Table 6-41.
 (h) Estimated at 100 lb water/10³ lb spent shale, which is equal to 10% by weight of 40,000 ton/day of disposed shale (cf. Table 7-11, Reference 10).
 (i) Consumption of 31 gpm for 1,600 people (see p. 207, Reference 10).
 (j) Mine use at 32 lb water/10³ lb mined out shale (see p. 195, Reference 10).
 (k) See Figure 6-14.
 (l) Based on minimum and maximum values of mine drainage water given in References 30-34, mine water for disposal may vary from about 1,500 gpm to 8,500 gpm.

Figure 6-14. Major water streams for modified in situ shale oil plant producing 57,000 bbl/day crude shale oil and 97 MW electricity. No surface retorting. Alternative schemes for handling more or less mine water than the 7656 gpm shown here are indicated in Figure 6-15.

Table 6-48
OVERALL WATER BALANCE FOR MIS + LURGI-RUHRGAS RETORTING SCHEME
PRODUCING 81,000 BPSD SHALE OIL AND 140 MW ELECTRICITY

<u>IN</u> (Makeup to plant or produced in retorting)	<u>10³ lb/hr</u>	<u>gpm</u>
Source (Mine water) ^(a)	3,442	6,884
Moisture in with shale, Lurgi-Ruhr gas retort ^(b)	68	136
MIS retort water; gas and oil condensate ^(c)	1,056	2,112
Runoff ^(d)	80	160
	<u>4,646</u>	<u>9,292</u>
<u>OUT</u> (Consumed or discharged)		
Steam to MIS retort ^(e)	848	1,696
Slurry water, Lurgi-Ruhr gas ^(b)	1,610	3,220
Water to saturate residue shale in retorted cavern	1,090	2,180
Dust control	148	295
Cooling water, evaporation and drift ^(f)	867	1,735
Potable, service; water consumed ^(g)	19	37
Losses, water treatment and steam cycle ^(g)	41	83
Losses, Lurgi-Ruhr gas retort and product gas ^(b)	23	46
	<u>4,646</u>	<u>9,292</u>

- (a) Water required for plant needs; not including excess mine drainage water.
 (b) As shown in Figure 6-17.
 (c) Taken from Table 6-39, MIS section.
 (d) Estimated surface area ~ 200 acres.
 (e) See Table 6-51.
 (f) 400 plant personnel in addition to the 1,600 mine/plant personnel for the MIS case.
 (g) As shown in Figure 6-18.

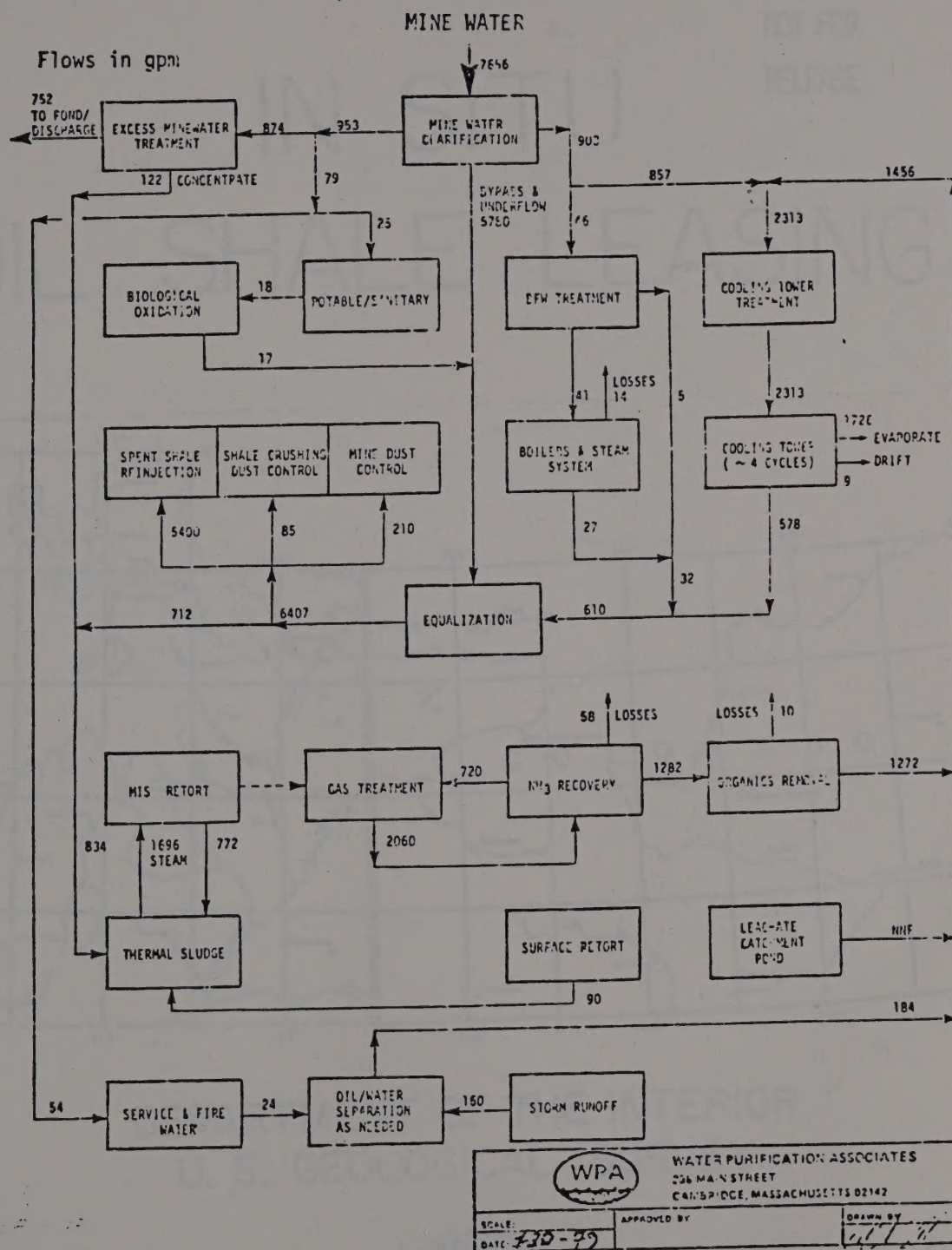
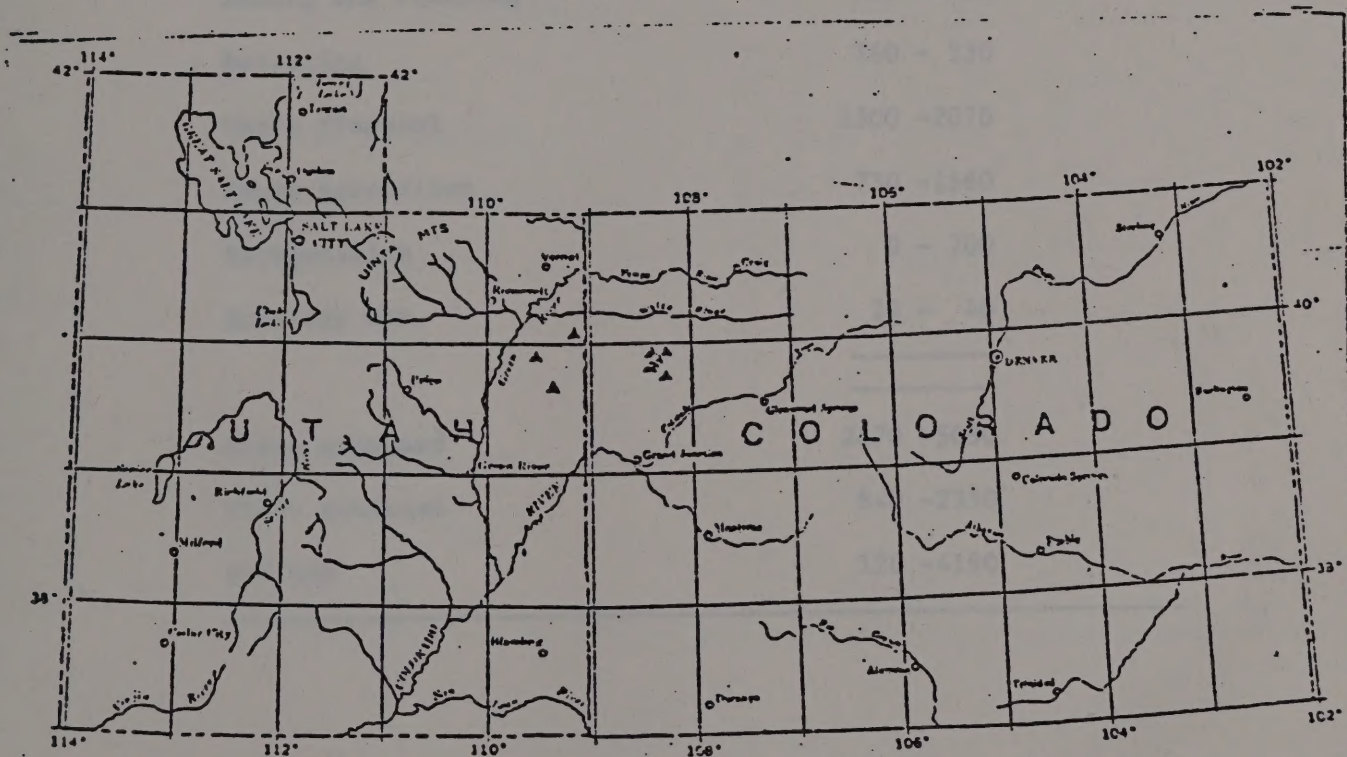


Figure 6-18. Major water streams for modified in situ Lurgi Ruhrgas shale oil plant producing 81,000 bbl/day crude shale oil. Minewater rate of 7,653 gpm from MIS scheme with no surface retorting.

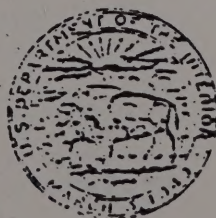
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Table 1-I .--Typical ontract water balance for 50,000 bbl/d
modified in situ development

	<u>Acre-feet per year</u>
Mining and crushing	160 - 230
Retorting	260 - 330
Shale disposal	1300 -2070
Power generation	730 -1660
Revegetation	0 - 700
Sanitary use	20 - 40
Water consumed	2470 -5030
Water produced	840 -2350
Deficit	120 -4190

Table 1-I-8 .--Typical ontract water balance for 10,000-bbl/
development by explosive fracturing

	<u>Acre-feet per year</u>
Mining and crushing	0
Retorting	0
Shale disposal	0
Power generation	0
Revegetation	0 - 140
Sanitary use	4 - 8
Water consumed	4 - 148
Water produced	170 - 470
Surplus	22 - 466

Table 1-I- ---Typical oncontract water balance for 10,000-bbl/d
development by solution mining

	<u>Acre-feet per year</u>
Mining and crushing	0
Retorting	13
Shale disposal	0
Power generation	60 - 140
Revegetation	0 - 140
Sanitary use	4 - 8
Water consumed	77 - 301
Water produced	135 - 170
Maximum deficit	166
Maximum surplus	93

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16. Abstract This report details work performed and results obtained in a study of the water management aspects of oil shale mining and retorting in the Piceance Creek Basin. Three specific sites were investigated, and optimal water management systems for both conventional and in-situ extraction processes were generated. Water-related legal and environmental constraints on development were identified and the water management schemes were developed in compliance with these regulations. Limitations on shale oil production implied by limited water supplies were evaluated. Potential Basin-wide effects of development were evaluated using a computer model, and mitigation strategies were developed. Recommendations for additional investigation and analyses were presented.					
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CHAPTER 14

WATER MANAGEMENT SYSTEMS FOR IN-SITU SHALE OIL INDUSTRIES

This chapter complements Chapter 11, which presented water management systems for conventional developments. The logic of presentation is similar. First the elements of the entire process are reviewed to determine net water use, broken down by required water quality. Then the system which best meets the net water needs is developed. This involves optimizing water supply, treatment, and disposal choices. Finally, the role of mine inflow is evaluated, in the light of water demand for the entire system.

14.1 WATER USAGE

14.1.1 True In-Situ Methods

In order to evaluate true in-situ methods, we have selected the only technique which has been demonstrated to be technically feasible: the method developed by the Laramie Energy Research Center. As described in Chapter 12, this process involves drilling a network of holes, hydrofracturing and blasting the formation, and igniting from a central hole. Oil, gas, and water are collected from outer holes. Very few details are available for water, power, and other variables which might be applicable to a commercial scale plant. However, we have scaled up to this size as well as possible at this stage, and the resulting water use table for a 30,000 BPD operation is shown as Table 14-1. This table may be directly scaled to other production rates.

Two cases are presented. The base case is the water use and production in the simplest conceivable industry: where power is provided from off-site sources, and steam is not

TABLE 14-1
WATER USE - TRUE IN-SITU CASES
(IN ACRE-FEET PER YEAR FOR A 30,000 BPD OPERATION)

<u>Use</u>	<u>Input</u>				<u>Output</u>	<u>Net</u>
	<u>Boiler</u>	<u>Service</u>	<u>Waste</u>	<u>Total</u>		
<u>Base Case</u>						
Site Development	-	57	-	57	-	57
Retorting	-	-	-	-	1,409	(1,409)
Upgrading	81	-	-	81	81	0
Miscellaneous	-	254	-	254	-	254
BASE CASE TOTAL	81	311	-	392	1,490	(1,098)
<u>Increments to</u>						
<u>Base Case</u>						
Steam Injection to Retorts	1,779	-	-	1,779	-	1,779
On-Site Power Generation	570	1,020	-	1,590	-	1,590
TOTALS WITH BOTH INCREMENTS	2,430	1,331	-	3,761	1,490	2,271

NOTE: Much of the material in this table is estimated. It should only be used in conjunction with the material presented in the text.

injected into the retorts to upgrade the off-gas. (Note that there are no published proposals to use steam injection for this purpose in true in-situ systems). The base case actually produces water at the rate of 1,098 AFY (682 gpm) because of the water liberated from the oil shale during retorting. This is equivalent to production of 0.8 barrels of water per barrel of oil. The quality of the water thus gained is assumed to be very low.

The second case is a maximum water consumption case for this style of mining. On-site power generation is assumed, and steam is injected into the retorts in order to upgrade the off-gas and thus allow its use for power production. It must be appreciated that the power required and the steam input necessary to produce higher quality gas have both been estimated, based on very indirect information. In this maximum use case, there is a relatively small net water demand of 2,271 AFY (1,412 gpm), or 1.6 barrels of water per barrel of oil produced.

Note that in both cases the water use for hydrofracturing the rock has been ignored. It is assumed that the retorts will be dewatered either during or after hydrofracturing. Thus this water will be collected by the dewatering system, and effectively recycled without consumptive use.

14.1.2 Modified In-Situ Method

The modified in-situ method water use is similar to the true in-situ usage, with the addition of mining and rock disposal water uses. The data upon which the evaluation is based is somewhat better than for the true in-situ case, as it has been partly taken from actual experience in the Basin. The results of the use evaluation are presented on Table 14-2.

TABLE 14-2
WATER USE - MODIFIED IN-SITU CASES
(IN ACRE-FEET PER YEAR FOR A 30,000 BPD OPERATION)

<u>Use</u>	<u>Input</u>				<u>Output</u>	<u>Net</u>
	<u>Boiler</u>	<u>Service</u>	<u>Waste</u>	<u>Total</u>		
<u>Base Case</u>						
Site Development	-	57	-	57	-	57
In-Mine Use	-	398	96	494	-	494
Rock Transport	-	153	-	153	-	153
Retorting	-	-	-	-	1,409	(1,409)
Upgrading	81	-	-	81	81	-
Revegetation	-	61	-	61	-	61
Miscellaneous	-	254	-	254	-	254
BASE CASE TOTAL	81	923	96	1,100	1,490	(390)
<u>Increments to</u>						
<u>Base Case</u>						
Steam Injection to Retorts	1,779	-	-	1,779	-	1,779
On-Site Power Generation	570	1,020	-	1,590	-	1,590
TOTALS WITH BOTH INCREMENTS	2,430	1,943	96	4,469	1,490	2,979

NOTE: Much of the material in this table is estimated. It should only be used in conjunction with the material presented in the text.

The base case is a minimum water usage condition, and produces a net water surplus of 390 AFY (242 gpm). This is equivalent to the production of 0.3 barrels of water per barrel of oil. Quality of this water will be very low. The maximum usage, which would appear to be the method most likely to be used in a commercial operation, consumes a net quantity of 2,979 AFY (1,850 gpm) of water. This is equivalent to the use of 2.1 barrels of water per barrel of oil produced.

14.2 WATER ACQUISITION AND TREATMENT

The usage quantities in the maximum use situations above are relatively small. Even for a 120,000 BPD operation, the largest to be considered under this contract, the net use is about 12,000 AFY or 7,400 gpm. It is expected that this quantity of water can be extracted from the groundwater system at any site (Chapter 5). As shown in Chapter 11, this is the least expensive form of water acquisition, and so it will be used here.

The cost of groundwater was evaluated in Chapter 5. Mine inflow water has no cost as a water supply, for it must be pumped out of the retort in any case. Groundwater pumped from a well system will cost \$30 per acre-foot at Sites 1 and 2, and \$90 per acre-foot at Site 3 (1974 dollars).

The cost of treatment of water is a more significant question. For the treatment technique selected (reverse osmosis), it is necessary to distinguish between input quantity and output quantity, as there is a certain amount of water removed in the concentrate. Table 14-3 presents the quantity relationships and costs for treatment of water to the required use standards.

RIO BLANCO OIL SHALE PROSPECT

REVISED

DETAILED DEVELOPMENT PLAN

TRACT C-a

RIO BLANCO PROJECT SUMMARY

VOLUME 3

- | | PHASE | COMMERCIAL PHASE |
|-------------------------|----------------------|---------------------|
| Timing | | |
| Construction | Sept. 1977-Oct. 1979 | June 1982-Jan. 1987 |
| Operation | | Begin Feb. 1987 |
| Site Development | | |
| One Production Storage | | 40,000 TFSO |
| One Refining (In Situ) | | |
| One Refining | | 200,000 TFSO |
| One Refining | | 100,000 TFSO |
| Processing | | |
| Refining | | 100 AT |
| Refining-Overground | | Modified In Situ |
| Produced Shale Refining | | Hot Conveyors |
- SECTION 6 ENVIRONMENTAL PROTECTION,
HEALTH & SAFETY
- SECTION 7 ENVIRONMENTAL ASSESSMENT
- SECTION 8 ENVIRONMENTAL MONITORING

Submitted To Area Oil Shale Supervisor,
Geological Survey, U.S. Department of the Interior,
Pursuant To Lease No. C-20046

Gulf Oil Corporation - Standard Oil Company (Indiana)

May, 1977

an initial rate of about 50,000 BPSD. Should future conditions warrant, production could be expanded to 76,000 BPSD.

All environmental assessment was based on 76,000 BPSD production rate. The assessments and models show that RBOSP can satisfy environmental stipulations and regulations at this higher production rate. They can easily be met at the rate of 50,000 BPSD since environmental effects will be reduced in proportion to plant capacity.

Table 1
RIO BLANCO PROJECT SUMMARY

	<u>MODULAR DEVELOPMENT PHASE</u>	<u>COMMERCIAL PHASE</u>
Timing		
Construction	Sept. 1977-Oct. 1979	June 1982-Jan. 1987
Operation	Begin Oct. 1979	Begin Feb. 1987
Mine Development		
Ore Production (Average Brought to Surface)	Retorts 1-5, 500 TPSD	40,000 TPSD
Ore Rubblized (In Situ)	Retorts 6 & up, 3000 TPSD	
Ore Haulage (Surface)	Up to 12,000 TPSD	134,000 TPSD
	Truck	Belt Conveyors
Processing		
Retorting-Surface	-	TOSCO II
Retorting-Underground	Modified In Situ	Modified In Situ
Processed Shale Haulage	-	Belt Conveyors
Products		
Shale Oil	Up to 4000 BPSD	76,000 BPSD
Sulfur	-	265 LTPSD
Product Movement	Truck (Shale Oil)	Pipeline (Shale Oil)
		Truck (Sulfur)
Net Groundwater Used	Up to 1000 AFY	2200 AFY
Power (Purchased)	Up to 40 MW	100 MW
Peak Employment	2500 for 76,000 BPSD	2075 for 76,000 BPSD
	1900 for 50,000 BPSD	1550 for 50,000 BPSD

G. Fire Protection Water - Adequate line sizes and storage capacity will be provided to comply with the fire codes. A storage capacity of 500,000 gallons will be reserved for fire protection use in the mine service area retention pond.

One 750 gpm diesel-driven pump and one 750 gpm electric motor-driven pump will provide fire water flow and pressure. Additional water supply will be available from the dewatering system pipeline.

H. Sanitary Sewage Treatment Facilities - A single commercial sewage treatment plant will be constructed in the mine service area to handle the sewage from the mine, the processing units and the construction operation during the MDP. Effluent from the sewage treatment plant will be stored in the mine service area retention pond and used for fire protection, process water and construction and haul road dust control.

6.3 COMMERCIAL PHASE

The estimated water usage during the Commercial Phase is shown in Table 6-6-2.

Table 6-6-2

WATER USAGE COMMERCIAL PHASE

Source	Use - GPM		
	Potable	Process	Dust Control
Upper Aquifer	60	-	-
Lower Aquifer	-	-	-
Mine Seepage	-	550	750
MIS Retort	-	1400	-
Surface Drainage	-	270	500
Total GPM	60	2220	1250

Groundwater usage, from upper and lower aquifers and mine seepage, amounts to about 1360 gpm or 2200 AFY.

OIL SHALE TRACT C-A

SUPPLEMENTAL

MATERIAL

TO

REVISED

DETAILED DEVELOPMENT

PLAN

SUBMITTED BY

GULF OIL CORPORATION

STANDARD OIL COMPANY

(INDIANA)

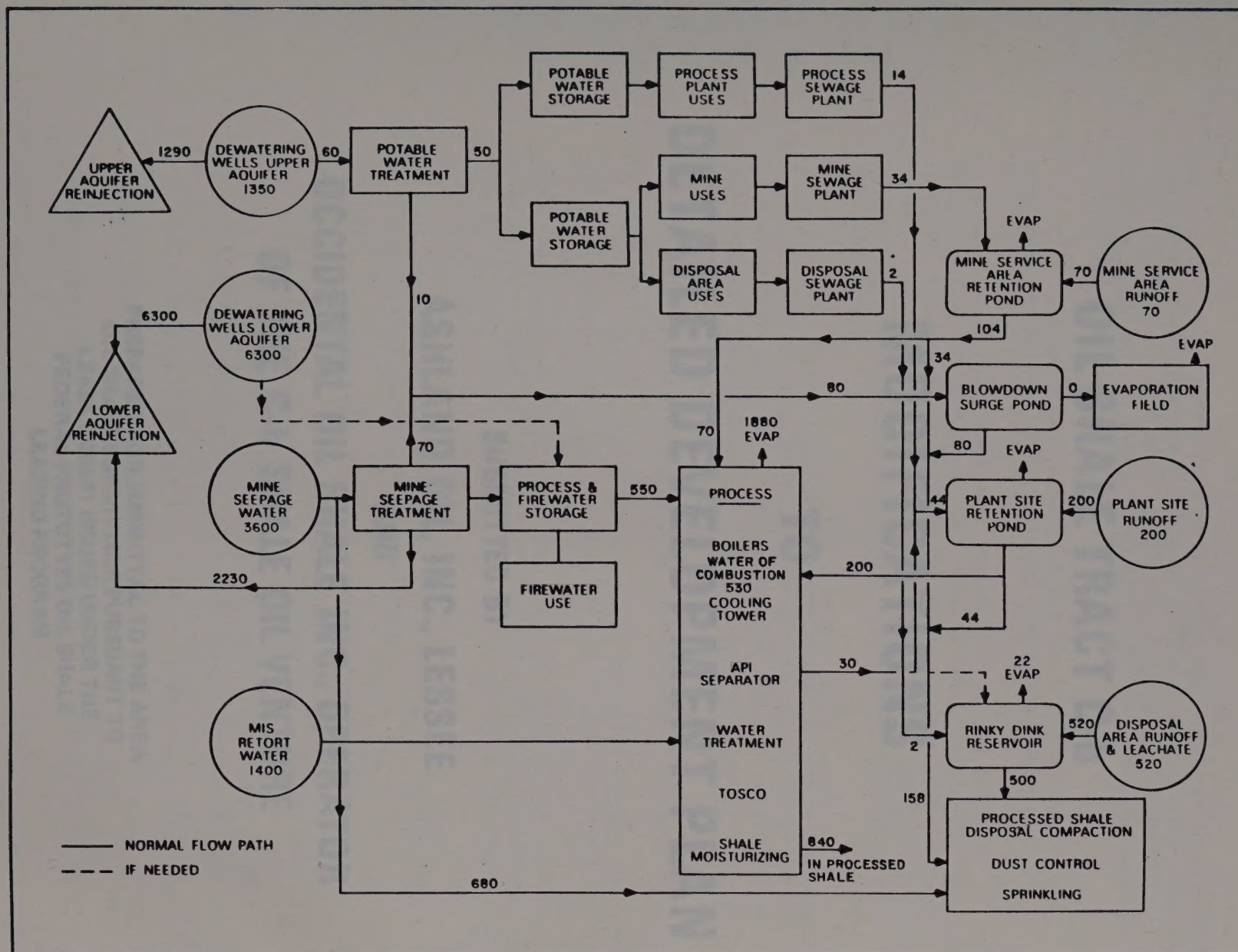


FIGURE 6-6-3
WATER FLOW - COMMERCIAL PHASE - GPM

OIL SHALE TRACT C-b

MODIFICATIONS

TO

DETAILED DEVELOPMENT PLAN

SUBMITTED BY

ASHLAND OIL, INC., LESSEE

AND

OCCIDENTAL OIL SHALE INC., OPERATOR

OF THE C-b SHALE OIL VENTURE

PREPARED FOR SUBMITTAL TO THE AREA
OIL SHALE SUPERVISOR PURSUANT TO
LEASE C-20341 ISSUED UNDER THE
FEDERAL PROTOTYPE OIL SHALE
LEASING PROGRAM

FEBRUARY 1977

A coronation diversion system will be used to divert rainwater around the shale disposal area and into the dam impoundment. Additional catchment ponds may be installed above the Sorghum Reservoir to capture sediment from the shale and prevent it from reaching the reservoir.

Water from the catchment ponds will be used to supplement needs for shale dust and compaction control.

It may be found necessary to retain and make permanent the Cottonwood Gulch temporary impoundment pond constructed earlier to collect runoff from the plant area drainage system. This water, depending on quality, would either join the Sorghum Reservoir water or be added to the lower-quality water for shale use.

The lined pond adjacent to the gas treatment area would revert from general water storage use to its final service as containment settling and concentration area for product water and process blowdowns.

8. Water Treatment, Use, and Disposal

One of the main sources of water to support project needs is envisioned, from preliminary hydrologic investigations by OXY consultants, to be from mine dewatering. It is anticipated that the amount of water available from the mine during development of the commercial plant will be more than required during the early stages and somewhat less than required after commencing full-scale operation.

Early investigation prior to initial development will define these estimates more precisely.

Comparison of Water Availability and Use

<u>Status of Mine and Process Plant</u>	<u>Estimated Mine Water Available (gpm)</u>	<u>Estimated Mine and Process Water Usage (gpm)</u>
Initial Retort Development	400 - 1,000	310
Retort Cluster Development	800 - 2,000	460
Commercial Operation	2,000 - X	2,500 gpm

III.E.8 (Contd)

From the above tabulation it may be seen that water needs during plant commercial operation are estimated to be ~~2,500 gpm.~~ Usage of water in the DDP showed a net plant requirement of 5,500 gpm (see DDP Figure IV-29).

Treatment of the mine water depends on the use of the water. Major uses include:

- (1) Untreated raw mine water: Dust suppression underground.
- (2) Filtered raw water: Feed for other treatment, utility service, fire protection and construction.
- (3) Treated water: Steam generation, process cooling, potable water for personnel use, and for discharge from tract.
- (4) Water treatment and process effluents: Dust suppression and compaction moisture for shale.

Water for underground drilling and dust suppression can be used directly from collection and settling sumps in the mine with no treatment. All water pumped from the mine to the surface will be clarified and filtered. Filtered water will be stored and transferred as needed directly to further treatment for other uses. It is planned that boiler feedwater will be treated by addition of chemicals for scale control, subjected to reverse osmosis to reduce dissolved solids and then deionized and deaerated. Potable water will likely require treatment by reverse osmosis, activated alumina filtration (to remove the fluoride ions), and chlorination before use. Various waste effluents from filtration, reverse osmosis, deionizing, and alumina filtration will be collected in a sealed settling pond and used to control moisture of shale for dust suppression and compaction control. Some evaporation and sludge settlement will occur in this pond as well.

The use of water during normal operations will total 2,500 gpm for the combined mining and in situ retorting plants. During construction, 500 to 750 gpm of water will be required for concrete manufacture, dust control, compaction of grades and fill, and other general and personnel uses.

All water supplied to the process plants will eventually be consumed or recycled or released to the atmosphere by evaporation. A major consumptive use of water is the moisturization of shale, for which all waste water streams not otherwise recycled will be used. Water used for moisturizing shale for reclamation or for dust control will either evaporate, be permanently incorporated into the waste pile, or drain into the

catchment basin for recycle. Other consumptive uses include steam generation in both the in situ and surface retorting plants for heating and process requirements, use as drinking water, evaporation losses and use as irrigation water in revegetation.

9. Waste Treatment and Disposal

During the construction period for the in situ facilities, small additional quantities of slash (small trees and brush) will be generated from surface clearing for site preparation. This material and other construction wastes will be handled as specified in DDP Section V-I.

During the operation of the full-scale plant, the wastes will be from two major sources: process wastes and sanitary wastes.

For the most part, process wastes will be generated from water and oil treatment systems and other blowdowns. Water treatment sludges will be ponded for evaporation, neutralized and either combined with the mined-out shale in solid form, returned to the spent retorts, or disposed of offsite in an acceptable manner.

Sanitary wastes will be treated onsite, recovering liquid values for reuse and disposing of solids along with process solid waste materials.

It is not anticipated that any waste streams pose a special problem. All treatment systems are expected to be conventional with precedence of acceptance within existing environmental and other regulations.

10. Roads

Final construction, realignment, and paving of the tract access road will be completed early in this period. It is expected that traffic density will be such that the need for final paving will be required at this time.

Additional in-plant service and access roads will be minimal during this period. It is anticipated that the only new roads to be added will be a graded dirt access to the relocated Cottonwood Gulch impoundment pond and conveyor service roads. Tract access roads will require 25 acres of surface during this period.

WATER-RELATED IMPACTS OF IN-SITU OIL SHALE PROCESSING

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Table 5-1. Comparison of net water consumption by surface and in-situ technologies. Excludes water demands for associated growth and includes water produced during retorting.

Process	Water consumption, gal/bbl	
	Surface ^a	Modified in-situ
Mining and crushing	23	12 ^b to 19 ^a
Retorting and upgrading	96 to 113	12 ^a to 28 ^c
Disposal of spent shale and revegetation	38	2 ^a to 19 ^b
Retort abandonment	0	10 ^d to 150 ^d
Power generation	25	26 ^c to 46 ^a
Miscellaneous	25	9 to 25 ^a
TOTAL	207 to 224	71 to 278 ^e

^aBrown et al., 1977.

^bGrew, 1977.

^cAshland, 1977 and Feb. 1977.

^dChapter 7, water consumption required to control in-situ leaching of spent shale. The lower value, 10 gal/bbl, is the amount of water required for intentional leaching with two pore volumes of water and 10 percent brine disposal. The higher value is the water required for grouting in-situ retorts with a slurry of raw or spent shale or other low-cost material. In this case, a credit of 50 percent may be taken for the water associated with the surface spent shale not disposed of and revegetated in the usual fashion, i.e., credit = 0.5 (19 gal/bbl) = 9.5 gal/bbl.

^eIncludes as a credit of 9.5 gal/bbl for spent shale used to grout in-situ retorts. See note d above.

less or more, about 71 to 278 gallons per barrel of oil. The amount of water required is strongly dependent on the type of technology used to control in-situ leaching of spent shale (Chapter 7). If no control technology is assumed for in-situ leaching, less total water is required for the in-situ processes because lesser quantities of raw and spent shale must be processed, handled, and disposed of. However, special control technologies may be

Table 5-2. Water balance for modified in-situ retorting with and without surface retorting by the Lurgi process (gpm).

	VMIS with Lurgi surface retort (81,000 bpd)	VMIS with no surface retorting (57,000 bpd)
<u>IN (Makeup to plant or produced in retorting)</u>		
Mine water ^a	6,884	2,102
Moisture in shale, Lurgi-Ruhrgas retort	136	0
Moisture in input air and shale and water of combustion	930	930
Storm water runoff	160 ^c	125
TOTAL	8,110	3,157
<u>OUT (Consumed)</u>		
Slurry water for Lurgi spent shale	3,220	0
Water to saturate spent shale in abandoned retort	2,180	0
Dust control	295 ^d	425 ^d
Revegetation	0	470
Cooling water, evaporation, and drift	1,735	1,634
Losses: potable, service, and fire water	37 ^b	31 ^b
Losses: water treatment, ammonia recovery, and steam cycle	83	82
Losses: Lurgi-Ruhrgas retort and product gas	46	0
Losses: MIS retort gas and oil	514	514
TOTAL	8,110	3,156

^a Water required for plant use; excludes excess mine water ponded or discharged.

^b The VMIS with surface retorting case includes 400 plant personnel in addition to 1600 mine and plant personnel for VMIS with no surface retorting.

^c Estimated for surface area of 200 acres.

^d Mine use dust control estimated at 32 lb water/10³ lb mined-out shale. Spent shale disposal dust control estimated at 100 lb water/10³ lb spent shale which is equal to 10 percent by weight of 40,000 tons/day of disposed shale.

Source: Nevens et al., 1979.

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